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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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J. G. VINCENT, *President* COKER F. CLARKSON, *Secretary* C. B. WHITTELSEY, *Treasurer*

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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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The Annual Meeting

THE program for the Sixteenth Annual Meeting of the Society which is to be held in New York City Jan. 11 to 13, is set forth herewith. Judging by the number of Dinner and Carnival reservation blanks which are coming in with each mail the attendance will be very gratifying to the committee members who are working diligently to maintain the reputation of this event. The program for the technical features has been arranged to cover those subjects of greatest interest at this time and sessions will be run simultaneously to enable a member to select the meeting relating to the subject nearest to his work. This innovation also allows more time for discussion of each particular subject and makes possible a more comprehensive presentation of the problem under consideration. Fourteen papers were presented at the Annual Meeting of 1920 and 14 at the 1920 Summer Meeting. There will be at least 22 papers for the coming Annual Meeting as a result of the decision of the Meetings Committee to hold simultaneous sessions. All of the technical meetings will be held in the Engineering Societies Building, 29 West 39th Street, where the general offices of the Society are located.

The semi-annual meeting of the Standards Committee will take place Tuesday morning and afternoon, Jan. 11. B. B. Bachman, chairman of the Standards Committee, will preside at these sessions and the chairmen of various Divisions will report on work done since the Summer Meeting. Several proposals for new standards and recommended practices will be discussed and voted on by the Standards Committee prior to submission to the general membership ballot.

Sessions

Since it is improbable that an Aeronautical Show will be held this winter it has been decided to hold the usual aeronautic sessions as a part of the Annual Meeting. The first is scheduled for Tuesday evening, Jan. 11, and will be presided over by Glenn L. Martin, second vice-presdent representing aviation engineering. C. D. Hanscom will outline the development of wing sections during the past year, discussing particularly the aerodynamic characteristics of the thick internally braced wing and sections suitable for effecting variable camber. Grover C. Loening will present a paper on recent airplane structural developments such as the all-metal plane, internally braced monoplane and retractable landing chassis. Major Thurman H. Bane will tell of the last six months' work of the engineering division of the Air Service at McCook Field, illustrating his talk with stereopticon slides and motion pictures.

The annual business meeting of the Society is planned for Wednesday morning, Jan. 12. The annual reports of administrative committees will be made at this time and officers for 1921 elected. Realizing the automotive engineer's opportunity and duty to bear a greater responsibility in industry during these times of economic readjustment, three prominent members have agreed to present their opinions regarding the Engineer's Place in Industry.

There will be three simultaneous technical sessions Wednesday afternoon, Jan. 12, covering Chassis Design for Fuel Economy, Body Engineering and Commercial Aviation. H. M. Crane, who will preside at the Chassis Session, will outline the many power losses, independent of the engine, which reduce fuel efficiency and deserve closer study. President J. G. Vincent and others have promised to express their thoughts on increased car efficiency, and the high fuel efficiencies attained by European engineers will be discussed.

The Body Engineering Session will be directed by Vice-President W. G. Wall. Several interesting papers are scheduled. Charles A. Heergeist, venerable carriage and body engineer, has prepared a statement on the reduction of body weight, and Andrew F. Johnson, educator of many of our foremost body engineers, has tendered some general remarks. George J. Mercer will handle the subject of body lines and predict the styles which he believes will prevail during 1921. George E. Goddard is planning to illustrate the steps in quantity production of all-metal bodies with some very interesting motion pictures.

The Aeronautic Session on Wednesday afternoon will be devoted to advances in commercial aviation. Glenn L. Martin will address the members. Ralph H. Upson has prepared a very comprehensive paper on the application of aircraft to the transportation of the immediate future. The development of commercial air transport lines in Europe since the war will be described by Prof. Edward P. Warner, of the National Advisory Committee for Aeronautics, who has recently returned from abroad.

Fuel Matters

Thursday morning, Jan. 13, will be occupied by a single technical session devoted entirely to the consideration of combustion phenomena of the present-day internal-combustion engine fuels. Past-President Kettering will disclose the results of extensive fuel research work carried on under his direction. The answers to a fuel questionnaire addressed to various members active in fuel problem study will be presented and discussed. The Fuel Session will be continued in the afternoon simultaneously with the Highway Session. Dr. H. C. Dickinson has some new Bureau of Standards experimental study to present and R. E. Fielder will describe a system of thermostatic inlet temperature control which has effected interesting economies as installed on the Fifth Avenue buses in New York City. The refiners' message will be carried to us at this meeting by F. A. Howard of the technical staff of the Standard Oil Co.

Past-President H. W. Alden, in opening the Highway Session on Thursday afternoon, will emphasize the responsibility of the automotive engineer in the making and maintaining of good roads. The Bureau of Public Roads has conducted a very extensive practical study of highway design during the past year and A. T. Goldbeck, the engineer of tests, who has directed this work, will present data and conclusions. The members will be specially interested in the report covering the tests on the impact of heavily loaded vehicles on the road surface. H. E. Breed, formerly Deputy State Highway Commissioner of New York, will present a paper entitled Variable Factors that Influence Highway Design, and W. E. Williams will give some suggestions on unconventional highway construction.

Carnival and Dinner

The Carnival Committee has completed all arrangements for that great social event which takes place Wednesday evening, Jan. 12. This year the large ballroom of the Hotel Astor will be specially decorated and prepared for the occasion and many surprises are in store for those attending. The Annual Dinner will be held Thursday evening, Jan. 13, also in the Astor ballroom. Mr. Kettering will carry the burden of toastmaster and that guarantees an evening with no flat spots. Reservation blanks for both Dinner and Carnival have been mailed to the members and it is advisable that all send them to the Society offices with the necessary check at once.

MOTOR BOAT MEETING

THE annual Motor Boat Meeting of the Society, held in New York City on the evening of Dec. 14, was attended by about 150 members and guests. An informal dinner preceded the technical session, Second Vice-President C. A. Criqui presiding. Mr. Criqui introduced William B. Rogers, Jr., directing editor of *Motor Boat*, who spoke briefly on the subject of standardized motor boats emphasizing the need for boats of uniform design in the smaller classes. He referred to a questionnaire circulated among the motor boat owners and builders throughout the world, the answers to which indicated the practicability of standardized designs. William Wadsworth Nutting, yachting adventurer extraordinary, narrated his thrilling double crossing of the Atlantic during the fall storm season aboard his 45-ft. auxiliary Typhoon. He outlined the entire trip but particularly stressed the encounter with an Atlantic gale off the Bermudas when the boat was swamped in the heavy seas and miraculously escaped foundering with all hands. Mr. Nutting's story was the more appreciated because of the very humorous and entertaining manner in which he told it. Henry R. Sutphen, president of the National Association of Engine and Boat Manufacturers, spoke extemporaneously on the development of the industry that would result from concentration on a few standard types of craft, and Ira Hand, secretary of the Association, called attention to the important work the Waterway League of America is doing for the advancement of motor boating.

Commander Holbrook Gibson of the Submarine Repair Base, League Island Navy Yard, Philadelphia, gave an illustrated talk on the surrendered German submarine Diesel engines which have been dismantled, reassembled and tested under his direction. He had discussed these engines at the last Motor Boat Meeting of the Society but the work of examination was not then sufficiently advanced to make possible detail consideration of such elements as the piston, connecting-rod, oiling system and reversing mechanism. The method of oil-cooling the piston-head was illustrated and the mounting of the piston-pin and bushing in the connecting-rod shown. The units described were all taken from four-cycle Diesel engines built by the Machinenfabrik Augsburg-Nürnburg, the reliability and operating simplicity of which were commended highly by Commander Gibson.

G. C. Davison contributed a paper entitled Commercial Motor Boats and the Diesel Engine, which was read by J. W. Anderson. It is generally believed that there are clearly defined fields in which one of the motor boat engine types is superior to the others, dependent upon installation and operation costs. Curves of these costs combined were presented for various horsepowers and periods of operation. Mr. Davison concluded from these curves that gasoline and kerosene engines are most economical in yachts and pleasure craft where powers are comparatively small and the boat operated less than 1500 hr. yearly. He believes that when the operation period is longer, it is more economical to select the hot-bulb or the Diesel engine, as determined by horsepower required. Diesel engines are, he thinks, superior to hot-bulb engines in sizes over 100 hp.

William Deed presented the engineering and manufacturing arguments in favor of the standardized motor boat as the naval architect views the question. He outlined the many economies resulting from continuous production of a standard type boat from the designing room, through the mold loft, mill and on to the ways.

Chairman Criqui voiced the general sentiment of gratification at the continually increasing interest and attention evinced at the S. A. E. Motor Boat sessions in the various marine engineering questions the proper handling and solution of which are essential to the advance watercraft propelled by internal-combustion engines.

Possible Fuel Savings in Automotive Engines[1]

By H. C. Dickinson[2] and S. W. Sparrow[3] *Illustrated with* Photographs and Charts

NOTHING need be said as to the importance of fuel conservation. "Familiarity breeds contempt," and the danger is that from constant discussion of this subject, its seriousness may fail to be appreciated. Nor is there any dearth of advice as to how to save fuel, either in the body of our trade journals or on the advertising pages. Unfortunately, the glowing terms of the advertisement deal too often with promises of what the carbureter, the fuel or the gas saver will do, and too seldom with records of what it has done. To be sure, the cost of fuel has not yet become a very large item in the cost of operation of most automotive appliances. In passenger cars, it is less than either tires or depreciation. A $2000 car will use some $500 worth of gasoline during its useful life and will wear out in so doing something like $800 worth of tires. What the repair bill may be depends mainly upon the driver and the repair man.

It is, however, fuel alone that is in danger of exhaustion and its conservation, therefore, is of the utmost importance. At the Bureau of Standards, the automotive section frequently has been called upon to test carbureters and fuel-saving devices of one kind or another and to pass upon their merits. As this work progressed, it became more and more evident that the difficulty of judging a given device is not so much due to inability to determine accurately what it did as to lack of knowledge as to what it should do. Of course, there was always available the ultimate test, namely, its performance on an engine with subsequent rating based on the measurements of power and fuel consumption. This, however, was not sufficient. The manufacturer who had exerted every effort to produce an inlet manifold with no sharp turns expected some statement of praise for his success in not impeding the passage of the gas to the cylinder, while at the same time the designer who had filled his manifold with a multitude of baffles expected equal commendation, for his efforts in "breaking up" the liquid. Research work, therefore, that would involve a study of some of the fundamentals of the problem and make it possible to predict the value of many of these devices without making extensive tests, seemed especially desirable.

The typical automobile engine, while representing a triumph of engineering as regards simplicity and reliability, leaves much to be desired in the way of fuel economy. At its best, running under full load and at normal speed, the thermal efficiency is from 20 to 25 per cent, i.e., this percentage of heat supplied by the fuel appears as an equivalent of work at the crankshaft. This, as it stands, is a very creditable showing, bettering that of the best steam engine by several per cent. But this is about the limit of the creditable showing. The engine seldom runs at anywhere near full load and its efficiency drops very rapidly as the load is reduced. Under ordinary road conditions, the efficiency probably does not exceed 10 per cent and of this 10 per cent, much is lost in transmission to the rear wheels and to the road. The subject of improvements in engine and vehicle design which shall result ultimately in increased mileage, is one of large possibilities and interest to the automotive engineer. However, with some 8,000,000 to 10,000,000 motor vehicles of present design in use and with an industry second in magnitude in this country, based upon and tooled for the production of present types of engine, the question of most immediate importance is: What are the possibilities of fuel savings in present types of equipment? The type of engine cannot be changed for a long time at best; and sizes of engine and car, their gear ratios and the like, can be changed only slowly. Such items as carbureters, manifolds and intake heaters can be changed more readily on new designs and to a limited extent on existing cars. Therefore, it is to improvements in fuel economy that can be brought about by such minor changes that the industry must look for immediate benefit.

Desirable Fuel and its Preparation

The problem is essentially one of diet. What kind of food shall be furnished the engine? How shall that fuel be prepared? To answer the first question is not difficult. The engine must be fed on whatever fuel is available and the only freedom of choice in the matter is in the mixture ratio, namely, the amount of air that is supplied with the fuel. The immediate possibilities of fuel conservation in existing engines can be summarized as follows:

(1) Avoid unnecessarily rich mixtures in the operation of all automotive vehicles as at present equipped
(2) Supply carbureter and manifold equipment on new and in some cases on older cars, which will make better fuel economy possible, or which will, in other words, cook the engine food according to the dictates of economy

Regarding unnecessarily rich mixtures, the numerous fuel improvers and dopes of various kinds marketed with guarantees to increase the mileage, remove carbon and generally improve the behavior of engines, are an evidence of the results which can be secured in many instances by inducing the driver to use a leaner mixture, as most, if not all, of the various improvers have absolutely no effect other than to induce the user to exercise more care in the use of the fuel. Numerous tests made for the sake of comparing average carbureter settings with the best settings for different cars have shown that without any other changes whatsoever, fuel consumption can be reduced, often by as much as 25 per cent. In fact, the long series of tests recently completed by the

[1] Paper presented at the meeting of the American Petroleum Institute, Washington, Nov. 17, 1920.
[2] M.S.A.E.—Physicist in charge of powerplants research, Bureau of Standards, Washington.
[3] M.S.A.E.—Associate mechanical engineer, Bureau of Standards, Washington.

Bureau of Mines to determine the composition of exhaust gases from average cars and trucks shows an excess fuel consumption of 25 to 30 per cent over that required for complete combustion. It must be concluded, therefore, that the average driver has his carbureter set much too rich for the best operation under average driving condition. What are some of the causes and the remedies?

An initial start with a cold engine can be obtained only when an amount of fuel equal to at least 5 per cent of the air in the cylinder is actually vaporized, or very finely atomized. With present commercial fuels, only a small percentage of the fuel will vaporize at ordinary temperatures. If, for instance, 50 per cent of the fuel can be vaporized, to secure an explosive mixture will require at least 100 per cent excess fuel.

While the time required for starting may be so short that the actual fuel loss is unimportant, the necessity of enriching the mixture makes the use of some choking device necessary and encourages the execssive use of this device while the car is in operation. Another important feature is the effect on the lubricating oil of the excess fuel that is drawn into a cold engine. The disastrous effects of crankcase dilution have been much discussed. There seems to be no question that the most serious dilution occurs in the starting and warming-up period. The saving of fuel and the prevention of crankcase dilution depend largely upon the care of the individual driver. Care in this regard will be well repaid in freedom from lubrication trouble, as well as in fuel savings.

During the period of warming up, excess fuel must be used. The same conditions apply as in starting, but to a decreasing extent. As the intake air, the intake manifold and the jackets become warm, the excess of fuel necessary to carry the requisite amount of vaporizable fractions decreases. The dash adjustment fitted on most vehicles at present permits the operator to control the mixture ratio at will. While this practice permits the careful operator to save fuel it also permits the careless driver to waste an excessive amount, and the economy which a careful operator can effect in this respect is important, particularly when a vehicle often is allowed to stand and cool off. The time required for thorough warming up is much longer than the driver is likely to suppose. The importance of properly protecting the engine when standing in cold weather should be emphasized.

It is in the setting of the carbureter for normal running that the major part of present fuel waste occurs and that the greatest savings can be secured. Two important causes for this extravagance are lack of patience on the part of the operator and an unreasonable demand for acceleration or "get away." If a carbureter is set so that the starting adjustment or dash control can be set to the lean or running position in say 5 min., or less in moderate weather with most cars, the mixture will almost invariably be too rich after another 5 or 10 min. of operation. There appears to be no remedy for this condition with present equipment, other than greater patience on the part of the driver. When there is a permanent carbureter adjustment with a dash control for warming up, the permanent adjustment should be made only after the engine has run for at least 30 min. In driving, the dash control should be set fully lean as soon as possible.

As will be demonstrated in the experimental program described later, the most obvious effects of mixture ratio on the behavior of an engine show up only when accelerating, but most driving involves frequent accelerations and, in fact, the response of the engine to a sudden throttle opening has come to be looked upon as an index of its behavior. Nevertheless, extreme performance in this regard necessarily means much waste of fuel, except in the rare cases where the intake manifold is sufficiently heated to supply a substantially dry mixture to the engine. Some sacrifice of extreme acceleration for the sake of fuel economy would seem to be amply justified, as the net results will be somewhat as follows:

(1) A saving in fuel of perhaps 25 per cent
(2) A great reduction in carbon in the cylinders, allowing probably two or three times as many miles between carbon removals
(3) An appreciable increase in maximum engine power, due to absence of carbon and a better and more rapidly burning fuel mixture
(4) Freedom from lubrication trouble attendant on crankcase dilution, assuring longer life for the engine
(5) Decreased cost of upkeep, less frequent overhauls being required
(6) A smoother running engine with less tendency to knock

In regard to carbureter and manifold equipment on new and on older cars that will make better fuel economy possible, there is considerable difference of opinion as to what constitutes the proper equipment for preparing the fuel for the engine. It is generally conceded that the food should be cooked, but it is a question whether this should be accomplished by the hot-spot manifold, concentrating the heat where the liquid strikes the walls; by the manifold completely jacketed by the exhaust so that the entire mixture is heated; or by the hot-air stove which heats only the air going to the carbureter. There still may be found some who persist in the belief that the fuel should not be cooked at all, but that it should be served in the fashion of 10 years ago when but little coaxing was required to vaporize the fuel and render it palatable to the engine. At the request of the Society of Automotive Engineers, considerable work was done in the past year toward determining the relative merits of the various methods of heating the charge.

The six-cylinder engine used in this investigation was furnished by a well-known manufacturer and exemplified good present-day design. But one change of importance was made in preparing the engine for the tests. This consisted in replacing the manifold supplied with the engine by one constructed so that it might be made to function as a hot-spot type, an entirely heated type or that type in which the air is heated prior to its entrance to the carbureter. The installation of this manifold and its construction are shown in Figs. 1 to 3.

The intake portion of this manifold was of cast iron and was surrounded by a jacket partitioned so that the exhaust gases could be made to heat the entire manifold, the tee alone, or could be by-passed, leaving the manifold cold. No comment is necessary on the apparatus for measuring the power, air flow, fuel consumption, and the numerous pressures and temperatures incident to the ordinary laboratory test.

Acceleration and Other Tests

It will not be amiss to call attention to two respects in which the equipment was unusual. The first of these was the provision for the study of acceleration. An analysis of engine requirements had emphasized the importance of ability of the engine to accelerate, to give the car what is frequently termed "pick up" or "get away." To measure this property, the so-called acceleration disc

was mounted on the dynamometer shaft. This was of steel 33 in. in diameter and ½ in. thick. Its inertia added to that of the dynamometer was about equal to that of a 3500-lb. car on direct drive with a gear ratio of 5 to 1 and 32-in. wheels. The second feature in which the set-up was novel is found in the large number of places at which temperature measurements were made. These were taken at no less than 25 points in and around the manifold.

The first series of tests was made at full load and half load at speeds of 650 and 1200 r.p.m. This covers a driving range of 15 to 25 m.p.h. In each instance, manifold conditions were as follows:

(1) Entire manifold unheated, air unheated
(2) Entire manifold unheated, air heated 30 deg. cent. (86 deg. fahr.), above (1)
(3) Entire manifold unheated, air heated 60 deg. cent. (116 deg. fahr.), above (1)
(4) Manifold tee heated, air unheated
(5) Manifold tee heated, air heated 30 deg. cent. (86 deg. fahr.), above (4)
(6) Manifold tee heated, air heated 60 deg. cent. (116 deg. fahr.), above (4)
(7) Entire manifold heated, air unheated
(8) Entire manifold heated, air heated 30 deg. cent. (86 deg. fahr.), above (7)

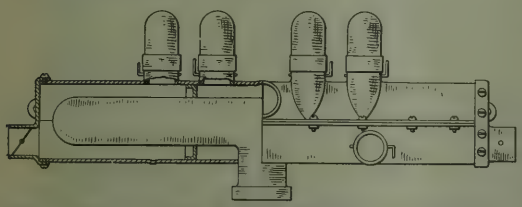


FIG. 1—SPECIAL JACKETED MANIFOLD EMPLOYED BY THE BUREAU OF STANDARDS TO STUDY MIXTURE CONDITIONS AND MANIFOLD HEATING

Figs. 4 and 5 on page 6 show the manifold under usual running conditions. Note the accumulation of liquid at the right and at the left of the tee, in the two successive illustrations. In one, at the instant of exposure, an intake valve is open at the left of the tee and, in the other, an intake valve is open at the right of the tee.

Fig. 6 on page 6 shows the manifold as it appears under good operating conditions at high engine speed, with the temperature of the incoming air at about 250 deg. fahr. Note that very little liquid is deposited on the manifold walls.

Figs. 7 and 8 on page 7 show the accumulation of gasoline in the manifold at about 10 m.p.h. when the throttle is opened wide after idling, with an air temperature of about 100 deg. fahr. Before opening the throttle, only a small amount of liquid is present. The liquid taken from the mixture to supply this amount on the manifold surface explains the difficulty and fuel waste in securing good acceleration with a cold manifold.

Fig. 9 on page 7 shows the result at 650 r.p.m. at full throttle, with an air temperature of 71 deg. fahr. The center of the tee has been heated with a brazing torch until liquid is evaporated from this portion. Note the liquid stream at the right and left of the central portion.

Fig. 10 on page 8 shows the result at 650 r.p.m. at full throttle, with an air temperature of 75 deg. fahr. One side of the tee has been heated with a brazing torch, the flame of which can be seen at the right. Note the effect of local heating in evaporating the liquid from the walls of the manifold on the right side.

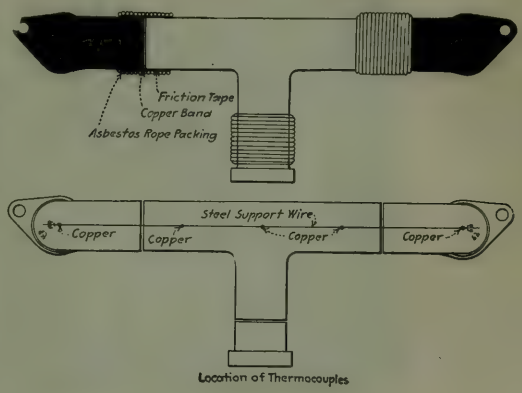


FIG. 2—THE GLASS MANIFOLD TEE

The matter of carbureter adjustment in these tests illustrates the value of planning the work so that the results shall have general application and hence be of permanent value. Had all these measurements been taken at but one carbureter setting, the data would have indicated merely the performance of this particular carbureter with this particular adjustment. Inasmuch as changing the amount of heat supplied to the charge is bound to affect the air-fuel ratio, it would have been difficult to know how much of the difference in performance to attribute to the change in heating and how much to the resulting change in mixture ratio. Instead of pursuing this course, the carbureter was given several adjustments at each temperature. Results could then be plotted to show the power developed from a given amount of fuel under the different methods of heating. Information thus obtained is not dependent upon the particular carbureter employed.

The results of two of these tests are shown in Fig. 11 on page 9. These were taken at one-half throttle at 650 and 1200 r.p.m., the conditions of heating being indicated. It will be noted that the difference between the curves is very small. The conclusion, then, is that over this range the power developed per pound of fuel is independent both of the amount of heat supplied and the point at which it is supplied. This statement must not be interpreted as applicable to every manifold. Obviously, if the area distribution of the fuel is very bad with a given manifold, fuel consumption will be reduced by the better distribution obtained by heating. It will be seen, however, that inasmuch as the type tested was of simple construction with no particular effort being made to obtain good distribution, there is little excuse for designs which are inferior in this regard.

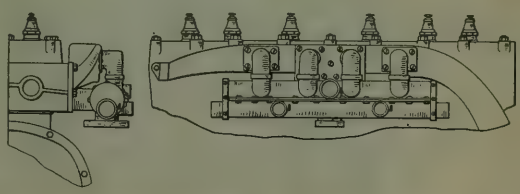
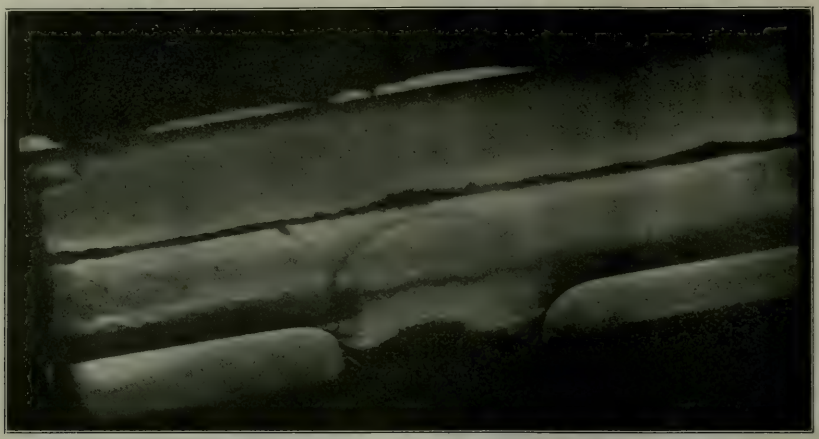
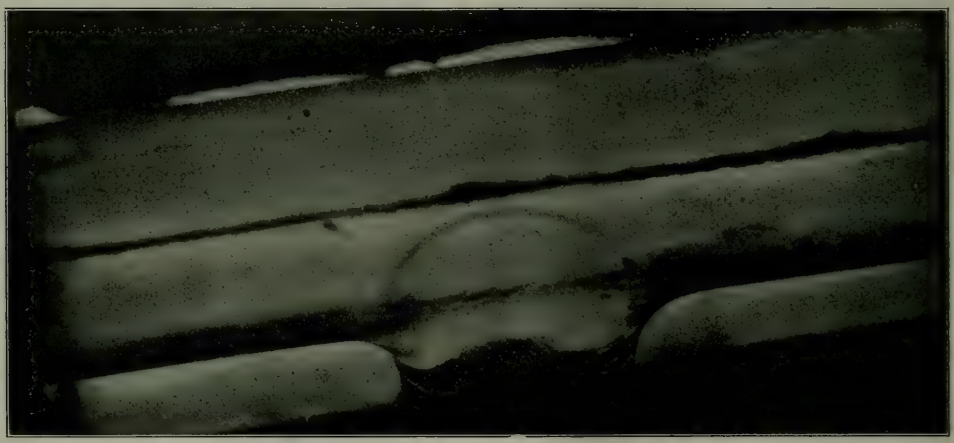
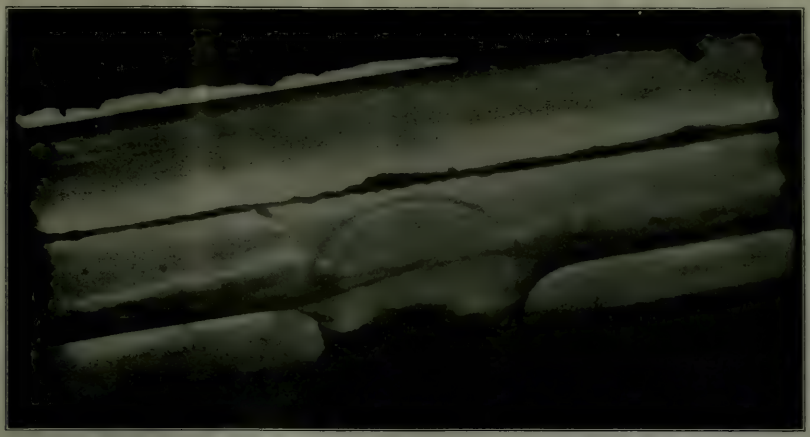


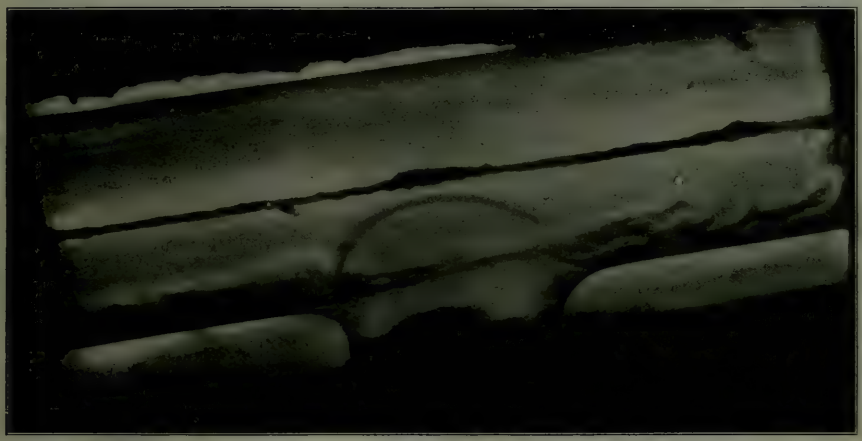
FIG. 3—THE SPECIAL EXHAUST-HEAT MANIFOLD INSTALLED ON THE ENGINE

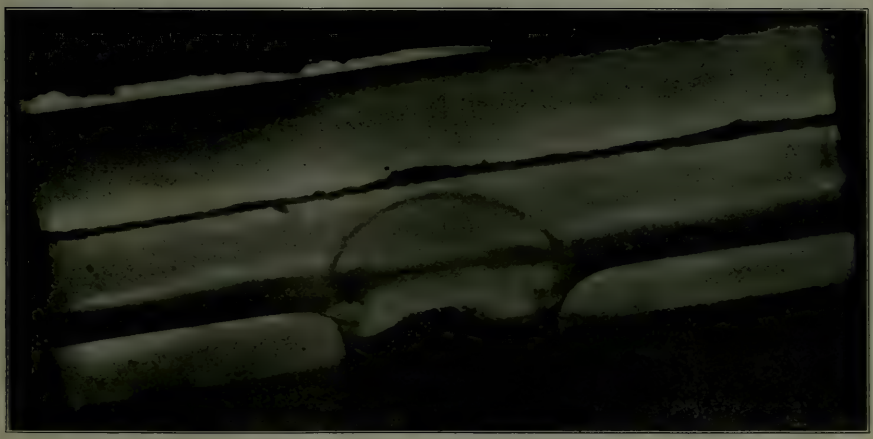




FIGS. 4, 5 AND 6—VIEWS OF MANIFOLD UNDER OPERATING CONDITIONS







FIGS. 7, 8 AND 9—THREE MORE VIEWS OF THE MANIFOLD

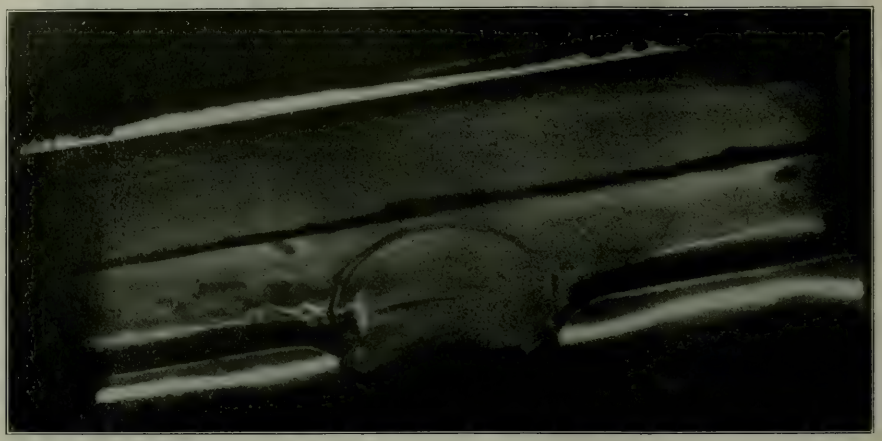


FIG. 10—A VIEW OF THE MANIFOLD WITH THE ENGINE OPERATING AT A SPEED OF 650 R.P.M. AND THE THROTTLE FULLY OPENED

JACKET-WATER TEMPERATURE AND INTAKE-MANIFOLD PRESSURE

There are two other subjects which receive considerable attention whenever fuel economy is discussed. These are the jacket-water temperature and the pressure in the intake manifold. It is asserted that with low jacket-water temperatures, the cool cylinder walls fail to supply sufficient heat to vaporize the fuel properly. As to the manifold pressure, there have been extraordinary claims made as to the better vaporization obtained when the intake is under a considerable suction and the boiling point of the fuel lowered because of this reduced pressure. Thus far, there has been opportunity to touch on but one phase of this problem. The results, however, are decidedly illuminating. Two series of tests were made: in the first of which the temperature of the water entering the jacket was maintained at 72 deg. cent. (162 deg. fahr.) and in the second at 22 deg. cent. (72 deg. fahr.). Runs were made at full load, also at 0.8, 0.6, 0.4 and 0.2 of full load, with five carbureter adjustments at each throttle setting. From these results, the minimum fuel consumption for each setting has been selected and plotted in Fig. 12. It will be apparent that the fuel consumption per unit power based on brake horsepower is considerably higher with the cold jacket water. Before drawing any rash conclusions as to the cause of this difference, it will be worth while to consider the lower curve. The same results are here given with the fuel consumption based upon the indicated horsepower of the engine; that is upon the power developed by the fuel in the engine cylinder. On this basis, the consumption is independent both of the load and of the jacket temperature. In this instance, then, there is no question that the poor economy with low jacket temperature should be attributed to the increased piston friction resulting from the higher viscosity of the oil on the cylinder walls, rather than to any change in fuel utilization.

As has been mentioned, the benefits of heating are most pronounced from the standpoint of acceleration. In making acceleration tests, a dynamometer load was selected to correspond to that of a car at about 45 m.p.h., the load decreasing with decrease in speed. With the dynamometer load set in this manner, the engine was idled and then the throttle suddenly opened. The inertia load of the inertia disc under these conditions corresponds to the inertia load of the car and the load-speed characteristics of the dynamometer approximate wind and frictional resistance of the car. Prior to each run, the engine was operated for a time at the constant speed of 650 r.p.m. and full throttle, to determine the fuel consumption under this load for the various carbureter settings used in the acceleration tests.

Typical time-speed curves are reproduced in Fig. 13. A mixture ratio of 9.4 to 1 at 650 r.p.m. and full throttle was used for runs Nos. 42 and 45 and no heat was supplied to the air entering the carbureter. Run No. 45 shows the acceleration from 800 r.p.m., while the unmarked curve at the right is typical of a badly loaded manifold. In a large number of tests, it was found that, with one exception, the richer the mixture is, the less is the time required for acceleration. Moreover, when additional heat was supplied to the intake air, the acceleration time decreased, regardless of the condition of manifold heating. The same acceleration time was obtained with a heated 15.3 to 1 mixture as with an unheated 9.4 to 1 mixture. As this represents a fuel saving of 60 per cent, there can be little argument as to the desirability of supplying adequate heat.

EFFECT OF HEAT ON MAXIMUM HORSEPOWER

This discusison would be incomplete without some reference to the effect of heat on the maximum power of the engine. Undue emphasis is frequently given to this phase of the problem and the fact that the engine is seldom operated for long periods at full load is overlooked. However, increasing the heat supplied the charge does decrease the maximum power of the engine, and it is usually the amount of this power that the manufacturer is willing to sacrifice to obtain good acceleration with an economical mixture that will determine just how much heating is employed.

To compare these tests with those made under different conditions, it may be essential to know just what intake temperatures were attained, how hot the hot-spot really was, the temperature of the exhaust gases, and the like. Such measurements were taken and Fig. 14 is a typical record. In one other direction, particular ef-

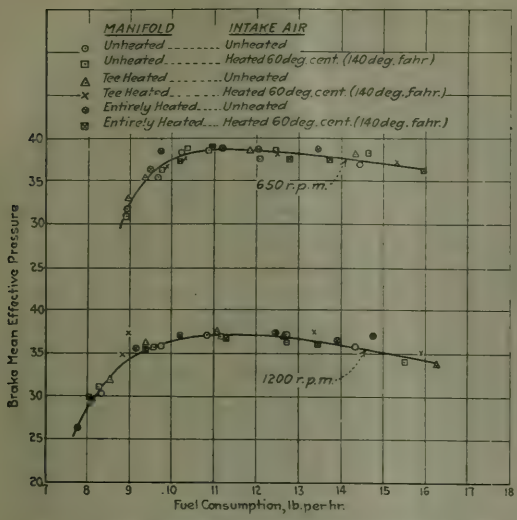

MANIFOLD
INTAKE AIR
Unheated ..... Unheated
Unheated ..... Heated 60 deg. cent. (140 deg. fahr.)
Tee Heated ..... Unheated
Tee Heated ..... Heated 60 deg. cent. (140 deg. fahr.)
Entirely Heated .... Unheated
Entirely Heated .... Heated 60 deg. cent. (140 deg. fahr.)
650 r.p.m.
1200 r.p.m.
Brake Mean Effective Pressure
Fuel Consumption, lb. per hr.

FIG. 11—CURVES SHOWING RESULTS OF TESTS MADE WITH THE THROTTLE HALF OPENED AT TWO DIFFERENT SPEEDS

fort was put forth to prevent the analysis of results being based too much on speculation and too little on knowledge. It would be unfortunate indeed to point out the benefits of a hot-spot manifold in vaporizing the liquid fuel that collects on the walls, without information as to where this liquid collected or as to whether it was thrown out of the air stream at all. Accordingly, prior to all of these runs, a preliminary series was conducted with a manifold having the tee section made of Pyrex glass. Motion pictures were taken, forming a perma-

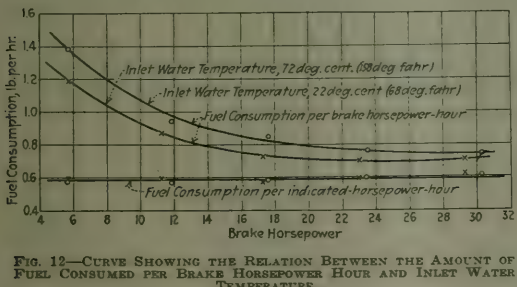

Inlet Water Temperature, 72 deg. cent. (158 deg. fahr.)
Inlet Water Temperature, 22 deg. cent. (68 deg. fahr.)
Fuel Consumption per brake horsepower-hour
Fuel Consumption per indicated-horsepower-hour
Fuel Consumption, lb. per hr.
Brake Horsepower

FIG. 12—CURVE SHOWING THE RELATION BETWEEN THE AMOUNT OF FUEL CONSUMED PER BRAKE HORSEPOWER HOUR AND INLET WATER TEMPERATURE

nent record of the observations. These testify to the existence of liquid in large amounts on the manifold walls and to the necessity for adequate charge heating.

SUMMARY

In summarizing the question of fuel savings, the possibilities naturally divide into two distinct classes, as to what should be expected from the engine operator and what the engine operator should expect from the designer and the manufacturer. The engine operator should avoid unnecessarily rich mixtures by carefully adjusting the carbureter, giving particular attention to the starting and warming-up periods of the engine. In addition, he should not demand unreasonable acceleration. He then has the right to expect the manufacturers to supply him with an induction system that shall supply fuel and air in the proper proportions, distribute it equally to the different cylinders and heat it adequately. Not only has he the right to expect this, but if the past performance of the industry be any criterion, he is practically sure of getting it, eventually.

A discussion of fuel saving would not be complete without consideration of the effect of quality of engine fuel on economy. Within certain limits, it is possible to burn a wide variety of fuels in present equipment with some degree of satisfaction. So long as no preheating device is used, the ability to start cold demands a rather definite percentage of the lighter constituents. No radical changes in this respect can be expected so long as the average car must be started without preheating the charge before starting. On the other hand, there is no

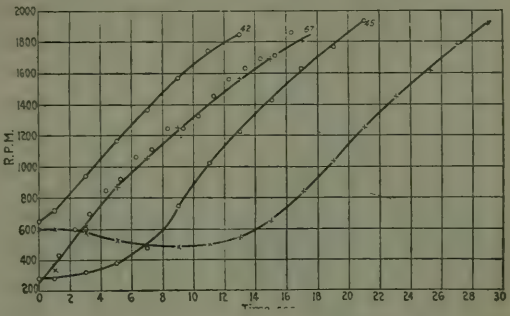


FIG. 13—TYPICAL TIME-SPEED CURVES

such definite and obvious limit to the addition of heavier constituents. There is no question whatever that increasing the end-point of fuels increases the fuel consumption in gallons per mile of the average car, for reasons which should be clear from the foregoing discussion, and this increase in specific consumption certainly becomes very rapid with an increasing end-point above about 400 deg. fahr.

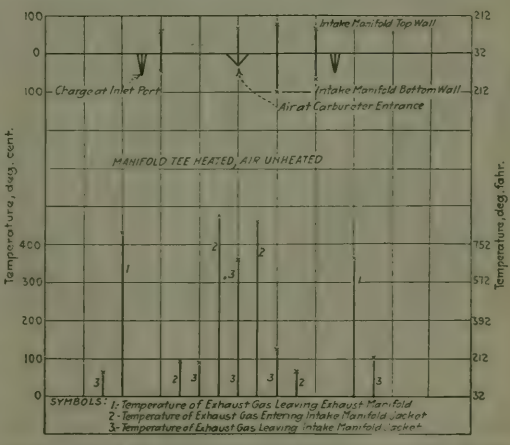
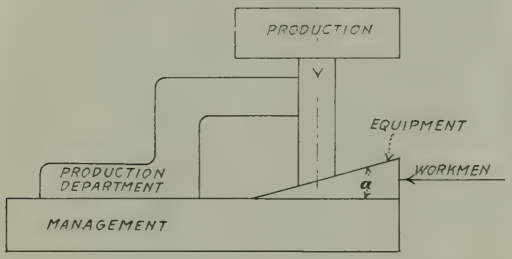

Intake Manifold Top Wall
Charge at Inlet Port
Intake Manifold Bottom Wall
Air at Carburetor Entrance
MANIFOLD TEE HEATED, AIR UNHEATED
Temperature, deg. cent.
Temperature, deg. fahr.
SYMBOLS: 1-Temperature of Exhaust Gas Leaving Exhaust Manifold
2-Temperature of Exhaust Gas Entering Intake Manifold Jacket
3-Temperature of Exhaust Gas Leaving Intake Manifold Jacket

FIG. 14—CHART SHOWING THE TEMPERATURE DISTRIBUTION IN THE INLET MANIFOLD WALL AND IN THE EXHAUST GASES AROUND THE INLET MANIFOLD

Friction in Organization

IN the analogy between mechanical friction and friction in an organization, attention is directed to the accompanying diagram which shows graphically the application of this factor of friction to an industrial organization. The men represent the power that exerts pressure on the wedge of equipment, which is supported by the management in raising the load of production, the latter being, in turn, supported or steadied by the production department. The friction between the load and the wedge is proportional to the load. To utilize this friction to the best advantage, the angle of inclination *a* should be such that it will sustain the load and at the same time prevent it from sliding by reason of its own weight. Any increase in the angle of inclination will result in a greater power requirement to raise the same load and will need more support from the production department. Conversely, a decrease in the angle will naturally result in lowering the production rate, unless greater manpower is supplied. The angle of equipment is composed of such items as machines, prime movers, adequate stock, timely deliveries, cooperation and all other factors entering into a modern organization. Each of these factors influences the angle and consequently affects all members of the mechanism.—J. B. Conway in *Machinery*.



GRAPH OF THE RELATION OF THE ELEMENTS OF AN ORGANIZATION AS REGARDS THE FACTOR OF FRICTION

CHICAGO AND COLUMBUS MEETINGS

THE arrangements for the annual Chicago dinner are approaching completion. This event, which accomplishes the same purpose in the Middle West as the New York dinner in the East, will be held Wednesday evening, Feb. 2, in the large ballroom of the Hotel Morrison. Harry L. Horning will be master of ceremonies for the evening; that assures plenty of hot-spots and general turbulence. A musical program of real merit under preparation by B. B. Ayers of the Meetings Committee promises to enliven things and add greatly to the evening's enjoyment.

The plans for the technical meetings call for a morning and an afternoon session, the motor truck and tractors being the principal topics for discussion. Many members have expressed interest in the engineering problems encountered by the men responsible for the maintenance and operation of large truck fleets and it is the intention that a valuable paper on this subject will be presented. The technical sessions also will be held in the Hotel Morrison.

The Columbus meeting and dinner will be held on Thursday, Feb. 10, during the week of the National Tractor Show. The dinner will be given at the Hotel Deshler. The location of the technical sessions will be announced in due course. Fred Glover will act as toastmaster at the dinner and E. A. Johnston will preside at the morning and afternoon technical sessions. Prof. O. W. Sjorgen of the University of Nebraska will present some constructive criticisms of present-day tractor design practice, based on the tests directed by him for the State of Nebraska. D. L. Arnold and John Mainland will report for their respective Tractor Standards Committee Subdivisions, outlining the results of recent work to determine proper plowing and belt speeds.

Tickets for the Chicago and Columbus dinners can be obtained now by writing to the offices of the Society, enclosing check to cover the number of tickets desired at $5 each.

STREET TRAFFIC IN LONDON AND NEW YORK

CROWDED as London is, at its most congested points, New York's traffic is undoubtedly heavier. The London figures show that on July 13, 1920, when the weather was fine, 43,505 vehicles passed Hyde Park Corner in the 12-hr. period when the count was made, and that was the highest total for any point in London. New York's center of heaviest traffic is Columbus Circle, with more than 50,000 vehicles passing in a 10-hr. day. The next busiest spot is Fifth Avenue and 42nd Street, where more than 41,000 vehicles and 129,903 pedestrians pass in a 10-hr. day. This is the largest number of pedestrians passing in any one spot. The latest account at Fifth Avenue and 34th Street showed 71,500 pedestrians in the 10-hr. day. These numbers, particularly of vehicles, are increasing every day. The number of vehicles of all kinds now using the streets of New York is very close to 400,000. This includes vehicles owned by residents of the city, those of commuters who drive into town and those of visitors from all parts of the country. This enormous total represents an increase of nearly 100,000 in the last year, and this increase has been caused largely by the expansion in the sale of small motor cars.

A comparison of the figures on street accidents will show that, in proportion to the population both the number of persons killed and the number injured are relatively about the same for London and New York. It is indisputable that most of the deaths are due to carelessness on the part of the persons killed.—Dr. J. A. Harriss in *The Evening Post*. (New York).

OIL POOLS

AN oil or gas pool or reservoir is not an underground cavern or "lake" filled with these products, but a porous rock body of sandstone, fissured limestone or other rock having continuous small openings and overlaid by shale, clay or other relatively impervious beds. These "cap rocks" are usually arched so as to entrap any oil or gas that seeps in, yet relatively tight areas in a given sand may surround a looser area of considerable magnitude, among the grains of which the oil is held until it is released by drilling operations. —C. T. Kirk in *Oil News*.

December Council Meeting

THE December Council Meeting, held in President Vincent's office at Detroit on the 4th, was well attended and a number of important subjects were discussed and disposed of. In addition to President Vincent, there were present First Vice-President Utz, Vice-Presidents Criqui, Martin and Wall, Councilors DeWaters, Germane and Johnston, Chairman Beecroft of the Meetings Committee, Joseph VanBlerck and Secretary Clarkson.

Financial Matters

Considerable attention was given to analyzing the financial reports made, these including, in addition to the regular statement of assets, liabilities and reserve, and of income and expense with budget comparison, complete detail figures on the operations of the Society during its last fiscal year, all of the items of income and expense being reduced to figures showing the relative loss or excess income per member per year in total procedure, by departments and according to each kind of work.

The balance sheet as at Sept. 30, 1920, showed that the net unexpended income for the fiscal year ended on that date was $19,556.12. This is about 7 per cent of the turnover, which was approximately $271,000. The total income for the last fiscal year was slightly in excess of $290,000.

The total income for the last fiscal year was $3,293.45 less and the total expense $22,849.57 less than had been contemplated by the budget. On Nov. 30, 1920, the Society had in hand Government and railroad bonds of a par value of $105,000, the purchase price of these having been $100,150.63; on the date mentioned their market value was $95,997. The total net assets of the Society on Oct. 31, 1920, amounted to over $200,000.

The accompanying diagrams show the proportional sources of income per dollar received and proportional expenditures per dollar expended by the Society in the last fiscal year; also the same information with respect to the total income and expense per member per year, the total income on this basis being $62.89 and the total expense $58.67.

The striking thing about the cost figures of the Society's operations is that, whereas the average of annual dues of members per year is $14.55, the cost per year per member is $58.67. The accompanying diagrams show clearly the relative expenses and revenues. The average initiation fee received by the Society is $22.05. The actual cost of inducting a new member is more than half this amount. It should be borne in mind and it cannot be ignored that the ratio of what each member pays to the Society to the expense per member consequent upon the Society's activities, is less than one to four. The cost of The Journal of the Society alone per

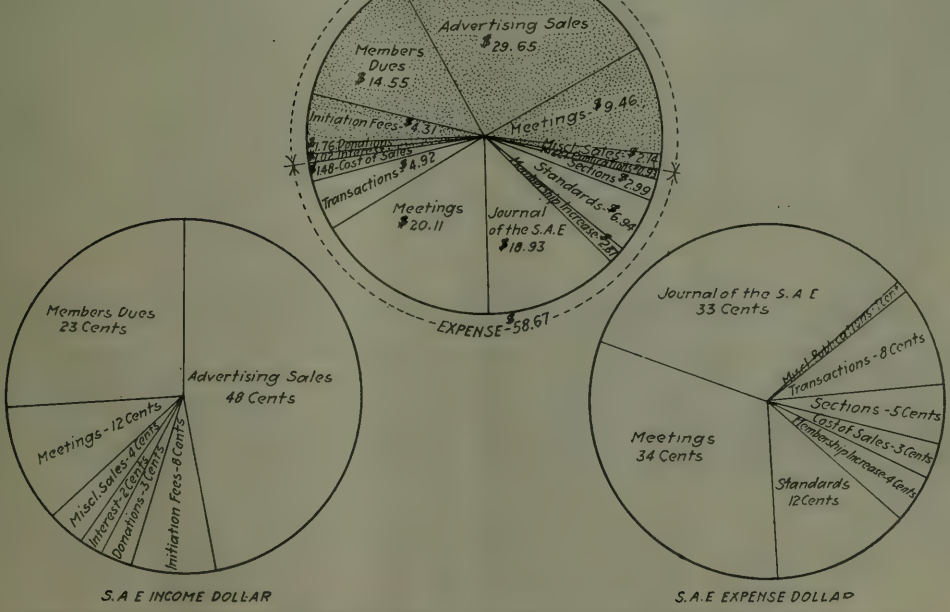


Chart Showing the Proportional Sources of Income and Expenditures per Dollar and the Distribution of the Total Income and Expenses per Member per Year

member per year is greater than the average annual dues. The same thing applies to the cost of the complete S. A. E. HANDBOOK.

In connection with the status of payment of accounts receivable by the Society, there is a noteworthy situation with regard to the annual dues. During the war the members paid their dues with about the same promptitude that they had paid them prior to the war. On Nov. 30, 1913, 55 per cent of the 1914 dues had been paid. On Nov. 30, 1920, 62 per cent of the 1921 dues had been paid. This is certainly very gratifying in view of current general financial conditions.

MEMBERSHIP

Two hundred and six applications were approved, 66 for Member, 4 for Service Member, 2 for Foreign Member, 81 for Associate, 49 for Junior, 1 for Affiliate grade of membership and 3 for Student Enrollment.

C. I. Bradley, F. I. Brown, F. C. Heath, E. H. Huesener, L. M. Klinedinst, N. B. Nelson, P. E. Norris, Joseph F. Sladky, S. W. Widney, H. R. Williams and Charles B. D. Wood were transferred from Associate to Member grade; R. W. Williams from Associate to Junior grade; and Foust Childers, L. A. Cummings, R. I. Dick, R. Karasinski, E. S. MacPherson, George J. Mead, Albert F. Miller, L. Ochtman, H. F. Peavey, W. H. Petit and A. F. H. Scott from Junior to Member grade.

One hundred and three applications for membership were received in November, as compared with 113 for the same month of 1919. On Nov. 30, 1920, there were 5230 on the rolls of the Society, including Affiliate Member Representatives and Enrolled Students, as compared with 4381 on the same date of 1919.

STANDARDS MATTERS

J. G. Carroll was appointed a member of the Commercial Vehicle Subdivision of the Electric Transportation Division.

The following new subjects were assigned to Standards Committee Divisions:

Rear End of Front Shaft of Three-Joint Propeller-Shaft—Truck Division
Differential Gears—Truck Division

A. J. Gifford was appointed as the representative of the Society on the Grinding Wheel Sectional Committee of the American Engineering Standards Committee.

In connection with the commercial use of aircraft and the necessity of proper national law in connection therewith being enacted as soon as possible, it was decided that the Aeronautic Division should be requested to formulate a special report, such as is provided for in the rules governing the Standards Committee, on regulations of commercial air navigation.

The Council confirmed the recommendation that the Society should organize jointly with the American Society of Mechanical Engineers, a Sectional Committee on Bolt, Nut and Rivet Proportions.

General Manager Clarkson was designated as the representative of the Society on the Executive Committee of the American Engineering Standards Committee.

The regulations governing the Standards Committee were revised in some minor respects. The complete regulations as now in effect will be included in the new edition of Vol. I of the S. A. E. HANDBOOK which is to be transmitted to the members at an early date.

SECTION AND SOCIETY MATTERS

The establishment of the Washington Section of the Society, in a reorganized form of the temporary organization authorized during the war, was approved.

After due consideration and discussion of the report of the Special Committee of the Council on the subject, the Council voted that the invitation to become a charter member of the Federated American Engineering Societies should not be accepted at this time.

It was formally determined that the Research Committee of the Society should be continued in reorganized form, superseding so far as shall prove feasible all previous committees appointed in the past for work related to research.

Discussion was had of the consideration that representatives of the Society office staff, together with members of the Society Fuel Committee, had been giving, in conjunction with representatives of the American Petroleum Institute and the National Automobile Chamber of Commerce, to the conduct publicly on a large scale through automobile dealers throughout the country or in some State of a Carbureter Adjustment Week, with a view to demonstrating what fuel economy can be attained by a carbureter adjustment which is considered technically correct. The consensus of opinion was that nothing of permanent value could be accomplished by such a proceeding in and of itself and that improved fuel economy must be attained through general educational methods and systematic policy in the servicing of cars.

The next meeting of the Council will be held at the offices of the Society in New York City on Monday Jan. 10.

SAFETY LESSONS FOR AUTOMOBILE DRIVERS

THE National Safety Council, Chicago, with the aid of automobile builders, driving instructors, traffic managers, repair-men and the representatives of practically every industry interested in any phase of the automobile accident problem, conducted a nine months study of the causes of accidents and means of eradicating them. This study has just been completed and the findings published by the Council in the form of a set of 12 safety bulletins and lessons for automobile drivers.

The lessons, covering every phase of motor-vehicle operation and maintenance which enters into the accident problem, will be distributed by the national organization through its local councils, automobile schools, clubs, insurance companies and every other channel which presents itself. For the Council feels that if it succeeds in making a set of the lessons available to every chauffeur and truck driver in the country it will mean annually a saving of thousands of lives, and the speeding up of automobile and motor-truck traffic through the elimination of lost time due to accidents which now amounts to thousands of hours daily in every big industrial center.

The lessons are printed on sheets 8½ x 11 in. On the reverse side of each is a safety bulletin illustrating some specific automobile hazard. Nine of the lessons are devoted to the maintenance of motor vehicles; the rest to their safe operation on city streets and country highways.

Pulitzer Trophy Race

THE race for the Pulitzer Trophy conducted by the Aero Club of America marks an epoch in the history of aviation. The winning of the race by an Army officer flying an American built airplane and the additional number of honors captured by American pilots flying American designed machines strike the highest note this country has contributed to aeronautics since the Wright Brothers wrought the miracle of the air at Kitty Hawk in 1908. Forty thousand people witnessed the race at Mitchel Field, Mineola, on Thanksgiving Day, and when Lieut. Corliss C. Moseley, driving his 600-hp. Verville Packard at an average speed of 3 miles per min. for the entire 132-mile course, made his smashing victory, the crowds became so wildly enthusiastic that they broke down the ropes and ran pell mell across the course to offer congratulations, despite the effort of the military police to restrain such a spontaneous demonstration.

Viewed from every aspect, the race stands prominently forth as one of the most successful aerial events ever held. The records made will not soon or easily be beaten, and happily of the total of 34 planes which made the start not one had a serious mishap, and not a single pilot suffered a serious injury. This means that the first of the Pulitzer races will mark the point in the history of aviation at which the public begins to realize that flying is, intrinsically, a safe means of locomotion provided the machines are properly built and driven by skilled pilots. It cannot but be a matter of immense satisfaction to the public at large that American machines gained so signal a victory over those of any other countries, and naturally the Army Air Service is not a little proud of the number of distinguished honors won by its officers and its airplanes.

Lieutenant Moseley's complete race record is as follows:

Lap	Time, min.	sec.
First	11	6.70
Second	11	0.37
Third	11	7.21
Fourth	11	15.32
TOTAL	44	29.57
Average Speed, m.p.h.		178

The achievement of Capt. H. E. Hartney, flying a Thomas-Morse 300-hp. Wright engine whose time was about 2 min. 30 sec. slower than Lieutenant Moseley's

THE 600-HP. VERVILLE PACKARD AIRPLANE WHICH WON THE PULITZER TROPHY RACE ON THANKSGIVING DAY AND MAINTAINED AN AVERAGE SPEED OF 178 M.P.H. FOR THE ENTIRE 132-MILE COURSE

was not less notable, his skilled driving of a "stock" plane eliciting the admiration of all aviators. Third prize went to Bert Acosta, one of the few civilian entries, flying the Italian Ansaldo S. V. A. with a 225-hp. engine while Lieut. St. Clair Streett, who commanded the Alaskan Flying Expedition, took fourth place with a 300-hp. plane.

It will be remembered that when Major Schroeder flew the Verville Packard in the International Race for the Gordon-Bennett Trophy at Etampes, France, last autumn, Lieutenant Moseley was his second pilot. In that event Sadi Lacointe won, establishing the world's race record, averaging for the course a rate of a little better than 169 m.p.h. for cross-country flying. Following the Gordon-Bennett race, one of the entrants, Count Bernard de Remenet, set up a new speed record by a straight-away flight at Buc Aerdrome by making a speed of 192 m.p.h.

While Lieutenant Moseley in no single lap of his flight in the Pulitzer event equalled the de Remenet straight-away speed of 192 m.p.h., his average of 178 for cross-country flying has Lacointe's average beaten, and so establishes a new world's race record.—Air Service News Letter.

POWER ON THE FARM

WE have people enough upon the farms of America today to make it impossible, at least within the life of the present generation, to have any shortage of food or to cut down materially our food exports or the raw products originating upon the farms, which go to manufacturers in American industry, if we can make farming a prosperous, contented, happy life and give to those young folks out on the farms the things which have been pulling them away from the farms and into the cities. There is nothing that will do that so quickly as the application of power to the farms, and there is nothing that will do it more rapidly than that wizard magic which has been invoked by the invention and the practical application of the internal-combustion engine. America in the next decade must intensify her production. She must produce more and more and yet more per unit of manpower and per unit of woman power upon the farms of this country to meet that which would otherwise be a very disastrous crisis. This will mean that upon the farms of America will go more gas engines until instead of 650,000 in the Mississippi Valley States, we will have 6,000,000, or two upon every farm, it will mean that instead of having about 450,000 tractors upon the farms of America, we will have about 2,000,000 or about 33 per cent of all the farms.—F. A. Odell in N. G. E. A. Bulletin.

Cleveland Tire Meeting

By Coker F. Clarkson

DURING the past 10 years over a score of standards relating to pneumatic and solid tires and rims therefor, as well as other closely related elements, have been established and reduced to practice with great benefit to tire manufacturers and dealers, automobile, truck and other automotive apparatus builders, and the users of rubber-tire-equipped automotive vehicles throughout the world.

Development of Tire Standards

This work was started by the Society of Automotive Engineers at the time the dimensions involved in the mounting of solid tires were standardized so that the tires produced by the various companies would interchange on the wheels with which motor trucks were regularly equipped. The next fundamental action of this phase of the work resulted in the establishment of four solid tire outside diameters as standard. Among the other important standards are deflection and set tests for pneumatic tire rims, pneumatic tire sizes, carrying-capacity tables for both pneumatic and solid tires and rim sections and contours for pneumatic tires. The organizations which, in addition to the Society, have taken part in the standardization proceedings, are the Tire and Rim Association (formerly the Clincher Automobile Tire Manufacturers Association, which was established for inspection work), the National Automobile Chamber of Commerce and the Rubber Association of America.

The principle upon which the tire standardization has been conducted is that tire products of different makers should interchange on the various automotive vehicles, that all structural elements of the equipment should be of adequate strength, and the lists of standard sizes not more extensive than necessary to meet clearly reasonable demands of design and operation, it being obvious that the fabrication and stocking of unnecessary sizes cause great economic waste.

Establishment of standards of this kind indicated is not easy. There is frequently lack of unanimity of opinion as to what should be done in a given matter, both among the tire manufacturers themselves and among the automotive vehicle builders, as well as at times between these two groups of "makers" and "users."

Genesis and Growth of Present Pneumatic Tire List

Fifteen years ago there was a demand which was entirely logical that the number of pneumatic tire sizes then being made should be reduced. The Mechanical Branch of the predecessor of the National Automobile Chamber of Commerce recommended a standard list of 10 tire sizes. Soon thereafter, however, the "oversizing" of tires came into vogue and the list of sizes again increased. Prior to that time pneumatic tires of different make would not interchange in rims therefor in general.

In 1915 a list of 18 pneumatic tire sizes was promulgated, nine of these being called "even sizes for regular equipment" and the others "odd or oversize tires" for purchase by car-owners only, that is not as original factory equipment. One of these sizes with its corresponding oversize was based on a 23-in. wheel or tire-seat diameter and two each on 24, 25, 26 and 27-in. wheel diameters.

In March, 1918, it was determined that all pneumatic tires, except the 30 x 3 and the 30 x 3½-in. sizes and their corresponding oversizes, should be of the straight side type. This left the number of "regulars" and oversizes at 18.

"War List"

In August, 1918, the 30 x 3, 32 x 4, 34 x 4, 36 x 4½, 36 x 5 and 38 x 5½-in. sizes were eliminated from the standard list, the 32 x 4 and 34 x 4 being replaced by the 33 x 4-in., the 36 x 4½ and 36 x 5 by the 36 x 6-in. and the 38 x 5½ by the 38 x 7-in. size. The 40 x 8-in. size was added at this time.

This reduced the total number of standard sizes to 10, seven of these being "regular" and three odd sizes as oversizes. Another important effect of this action was to eliminate the 26 and 27-in. wheel diameters, leaving one tire, the 30 x 3½ clincher, to be mounted on a 23-in. wheel, and three each on 24 and 25-in. wheels. This of course tended to reduce the number of wheel diameters in use from five to three.

Restoration and Addition of Sizes

In the next year, 1919, as a result of insistent demand from builders of certain types of car, the old 32 x 4-in. size and a new 32 x 4½-in. size were added to the standard list. The result of this, so far as wheel diameter is concerned, was the mounting of straight-side tires as follows:

Nominal Tire and Rim Size, in.	*Tire Seat Diameter, in*
32 x 3½	25
32 x 4	24
33 x 4	25
32 x 4½	23
34 x 4½	25
36 x 6	24
38 x 7	24
40 x 8	24

This increased the total number of tire sizes, including the 30 x 3½ and 31 x 4-in. clinchers, to 13.

In March, 1920, the 33 x 4½-in. oversize was included in the list of regular sizes, as well as continued in the list of oversizes. A new regular size, 34 x 5 in., was added, this serving as an oversize for the 33 x 4½-in. size. In addition, the 42 x 9-in. size was included in the regular list, and as an oversize for the 40 x 8-in. size. This involved the use of wheel diameters as follows for straight-side types:

Nominal Tire and Rim Size, in.	*Tire Seat Diameter, in.*
32 x 3½	25
32 x 4	24
33 x 4	25
33 x 4½	24
32 x 4½	23
34 x 4½	25
34 x 5	24
36 x 6	24
38 x 7	24
40 x 8	24
42 x 9	24

This increased the total number of tire sizes, including the two clincher-type sizes to 15, 12 of which were in the regular series.

In August, 1920, the 42 x 9-in. size was replaced by the 44 x 10-in. size as a regular size. This made the total number of standard pneumatic tire sizes 16. In this connection it should be borne in mind that in the recent standard tables for pneumatic tires, the sizes for both passenger cars and motor trucks have been included. About 10 sizes, including two clinchers, are used extensively for passenger-car new equipment at this time.

Current Considerations

At a joint meeting of the Tire and Rim and the Truck Divisions of the Society held at Cleveland in November, with a number of passenger-car engineers and representatives of the National Automobile Chamber of Commerce, the Rubber Association of America, the Tire and Rim Association, the Motor Transport Corps and the Bureau of Standards in attendance, several important questions were considered, one main purpose being to coordinate the standardizing effort of the various interests involved, there having been controversy as to the manner of conducting the tire standardization work. At a recent meeting the Council of the Society reiterated the opinion that as a matter of principle designers of automotive apparatus should participate in the formulation of tire standards.

During the summer the Society had canvassed the industries involved on the proposal submitted to it for transmission to the vehicle builders, that the ultimate standard list of pneumatic-tire sizes should include only sizes mountable on the 24-in. wheel. J. E. Hale, of the Goodyear Tire & Rubber Co., which had advocated this proposal strongly, said at the Cleveland meeting that one tire diameter for each cross-sectional diameter of straight-side tire ought to be sufficient; that such practice would reduce the cost and improve the quality of tires, rims, wheels, axles, speedometers and other parts of cars; improve greatly distributing and stocking conditions, and result in tremendous economic saving to the industry as a whole and a saving in service to the consumer. He stated that the Goodyear company advocates having tire sizes that all fit one rim diameter, because it is desirable to oversize right through the line of tires.

In opposing the proposal, J. C. Tuttle of the Firestone Tire & Rubber Co. referred to the changes that had to be made in the list of standard pneumatic-tire sizes that had been promulgated during the war.

G. P. Dorris made a strong plea for the retention of the 33 x 5-in. tire.

Past-President Marmon addressed the meeting on behalf of the Cole, National and Premier companies, as well as his own company. He expressed the view that standardizing on the 24-in.-wheel series of tire sizes would handicap engineering effort and impede the development of cars of greatest economy from the standpoint of maintenance.

W. H. Allen of the B. F. Goodrich Co. stated that the tire industry is opposed to the 24-in. wheel plan. He questioned the wisdom of considering pneumatic tires jointly for passenger cars and trucks, feeling that truck-tire practice may change considerably.

Practically all of the pneumatic tires used on trucks are mounted on 24-in. wheels. F. A. Whitten of the General Motors Co. said that the truck builders favor conditions that permit oversizing of tires without difficulty.

The following resolutions were passed at the meeting in connection with the standard list of pneumatic-tire sizes:

> The 24-in. wheel is not the only desirable one to use, and the present standard of pneumatic tire and rim sizes is satisfactory.
>
> A small committee, composed of tire, motor truck and passenger-car members, should be appointed to investigate the problem of reducing the number of standard sizes of pneumatic tire to the lowest possible minimum, with a view to presenting the facts to the National Automobile Chamber of Commerce, the Rubber Association of America and any other interested body, and requesting specifically that these bodies take the matter up from the commercial point of view.

While these resolutions had, so far as committing the Society under its rules of procedure in standards matters is concerned, only the status of straw votes, the Council of the Society at its meeting held last month appointed, in response to the passage of the resolutions, the following committee:

J. G. Vincent, President of the Society (Chairman)
H. H. Rice, Chairman National Automobile Chamber of Commerce Tire Committee
A. L. Viles, General Manager of Rubber Association of America

Limits for Oversize Tires

The executive committee of the Tire Manufacturers' Division of the Rubber Association recommended in September last that the actual cross-sectional width of pneumatic cord tires when inflated in accordance with the S. A. E. Standard be not less than the nominal width marked thereon or greater than 10 per cent in excess of such nominal width; it being understood that the nominal width of the so-called 5-in. tire shall, in accordance with custom, be considered 5¼-in.

It is considered very important that limits should be prescribed for the actual outside diameters of the respective nominally dimensioned tires, as affecting gear ratios, speedometers, body and fender clearances, vehicle turning radius, brackets for spare tires and the use of non-skid devices. Granting that the tire manufacturers or a large proportion of them will follow the Rubber Association recommendation as to dimensional limits of tire cross-sectional width, it is apparent that the only way the actual outside diameter can be controlled is by limiting the amount of tread placed by the tire manufacturers on carcasses of given sizes.

Metric Sizes

For several years the desirability has been appreciated of having lists of reasonable length for metric sizes of pneumatic and solid tires for export. The question is one of feasibility and practicability. The Society is now interchanging data with foreign organizations. The subject is one in which commercial as opposed to engineering considerations are largely the determining factors. Sales matters have much weight, of course, in all of the tire standardization work; which is one and probably the greatest reason for the difficulty and complexity of it. The above named committee will take under advisement the problem of the metric tire sizes.

Interchanging Front and Rear Pneumatic Tires on Trucks

With the increasing use of pneumatic tires on motor trucks has come the problem of obviating the necessity of carrying more than one spare rim and tire for use in case of tire change on the road. This problem has assumed serious proportions on account of the lack of

interchangeability of rims and tires as between front and rear wheels. The truck industry requested the Society to investigate the situation and accomplish standardization permitting interchanging 36 x 6, 37 x 8 and 40 x 8-n. rims and tires between front and rear wheels. The metal wheel manufacturers also have indicated their interest in the matter. The subject was discussed at the last meeting of the Society and a special meeting of the Tire and Rim Division was held to consider possible means of securing the desired interchangeability. The members discussed several suggestions, one of which was to use two adapter rings, one for the normal-size rim on a wheel and the other for the oversize rim on the same wheel. This was not considered advisable, however, in part because of the possibility of double oversizing tires which is not approved by the tire manufacturers for truck work.

The tire industry felt that truck design should be further investigated with a view to securing more even distribution of weight between the front and rear wheels, to permit the development of a suitable rim for interchangeability of tires between front and rear wheels without the necessity of carrying additional spare parts to those currently used on the truck. It was decided, however, to attempt to lay out a single set of wheel rim or felloe dimensions for the 5, 6, 7 and 8-in. tires.

The truck engineers were canvassed on the truck weight-distribution question, but the great majority of those replying were decidedly averse to considering seriously much modification of present practice in this respect.

At the Cleveland meeting George L. Lavery of the West Steel Castings Co., submitted for consideration sketches of construction for use in emergency interchange of 6, 7 and 8-in. tires, eliminating adapter rings. The sketches met with some favor and were studied in revised form at the meeting of the Truck Division held on the day following the general tire conference.

HIGHWAY RESEARCH

THE following national organizations have been asked to appoint representatives on the Advisory Board on Highway Research of the National Research Council:

American Association of State Geologists
American Association of State Highway Officials
American Institute of Consulting Engineers
American Automobile Association
American Concrete Institute
American Railway Engineering Association
American Society for Testing Materials
American Society of Civil Engineers
American Society of Mechanical Engineers
American Society of Municipal Improvements
Bureau of Public Roads, Department of Agriculture
Division of Geology and Geography of National Research Council
Federal Highway Council
National Automobile Chamber of Commerce
National Highway Traffic Association
Society of Automotive Engineers
University Highway Engineering Departments
War Department
Western Society of Engineers

There is urgent need for a systematic, thorough, comprehensive research program that will place our road building on a sound scientific engineering basis and enable the country to spend effectively the large sums involved. The need is realized in many quarters and several agencies are at work; but their work is uncoordinated, incomplete and overlapping. To secure cooperation of the numerous existing agencies and through such cooperation bring about the concentration of the talent of the country and avoid duplication, a conference was called recently. It is the intention to secure a definite assignment by Congress of a certain portion of the unexpended balance of Federal-aid road money to some agency that will administer the funds under the direction of the Advisory Board. It is hoped that sufficient funds will be made available immediately to allow the research work to begin.

AMERICAN MERCHANT MARINE

THE American carrying trade to and from United States ports showed a steady increase in tonnage for the fiscal year ended June 30, 1920, but, during the same period foreign carrying trade to and from our ports increased at a more rapid rate than our own trade, with the result that American ships in July carried less than 50 per cent of our total foreign commerce. American ships carried about 57 per cent of our July trade with North America, about 55 per cent of our trade with South America, and less than 30 per cent of our trade with Europe.

The way has been opened for increasing the importance of the United States as a maritime nation. For 60 years a large proportion of the profits of American industries has gone overseas in the form of ocean freight charges, marine insurance premiums and banking commissions, and the toll has aggregated billions of dollars. From 1870 to 1890 alone, foreign ship owners collected more than $3,000,000,000 from us. In the fiscal year which closed shortly before the war the bill amounted to nearly $400,000,000, and last year, it is estimated, this country paid an amount exceeding $700,000,000 to enrich our competitors on the high seas.—Guaranty Trust Co.

DETROIT HOUSE NUMBERS CHANGED

IN connection with the renumbering of the houses in the delivery area served by the Detroit post office which became effective Jan. 1, the records of the Society have been corrected to show these new numbers. Members of the Society located in Detroit, Highland Park and Hamtramck are urged to inform the office of the Society in New York City promptly of all instances where communications are delayed in delivery by reason of their being addressed to old house numbers. It is only by the cooperation of all of our members that it is possible for the Society to maintain accurate records. The membership at large and especially those residing at Detroit and in the immediate vicinity are requested to send in all changes of addresses promptly to the headquarters of the Society at New York City.

Impact Tests on Trucks

By E. B. Smith[1]

Semi-Annual Meeting Paper

THE United States Bureau of Public Roads has recently started an elaborate investigation of soils as related to road construction. This investigation will extend over considerable time and cover a large part of the United States, taking into account all kinds of soil and road conditions. We are also investigating the forces which tend to break up and destroy roads.

The most destructive force received by a road is that of impact. For the past year we have been studying this force, but have been delayed by weather conditions many times. In the beginning, we found it necessary to develop means of measuring impact forces. This was done by receiving the impact on a small copper cylinder and measuring the deformation of the cylinder. Then, any impact force that would produce the same deformation in the copper cylinder can be stated in terms of the equivalent static force. This is somewhat approximate, but is a proper comparison within certain limits. Even when we know what static or equivalent force produces the same deformation in a copper cylinder, this does not tell the whole story because an impact force is much localized and produces shattering effects. The copper cylinders for measuring this force are all carefully heat-treated for uniformity and calibrated for static deformations so that, after the impact has been received on the copper cylinder we determine its static equivalent approximately. An apparatus is being developed which is to be installed on a truck or an automobile. Then, if the truck so equipped is run over any type of road under any given speed and load conditions, we can obtain the impact values, which will enable us to pick out the conditions which give us the destructive impact values. The impact values we have secured will run as high as 43,000 lb. If we imagine a road able to withstand such an impact for any length of time, it would probably be one of very thick reinforced concrete.

These impact values are largely dependent upon the type and construction of the truck. Unsprung weights have a great influence upon the impact value of the blow on the road surface and a reverse influence upon the body of the truck, as perhaps may be felt by the cargo or by a passenger. Those effects are in two different directions. Our present aim is to investigate this impact and the effect of the unsprung weight on the road. The impact force, as received from the unsprung weight, is a result of the acceleration due to gravity and to the pressure or kick of the spring. It may be seen readily that the product of mass times the acceleration gives a maximum impact force when the mass of the unsprung weight is the greatest. If two masses are taken, one supported on top of the spring and the other below the spring, and dropped from a height of several feet, the resulting impact as it strikes the pavement will be comparatively small; that is, small in comparison to a case where that same combination is dropped from a small height of 2 or 3 in., this combination being released from a support under the spring in either case, thus allowing the spring to kick downward. The resulting impact blow would be much greater in the latter than in the former case.

Most of the tests have been made on solid tires. A few have been made on worn solid tires and some on pneumatics. There is a large difference in the impact value of a new and an old solid tire. The impact value for old and badly worn solid tires increases as much as 45 to 75 per cent. The impact is greatly reduced by the use of pneumatic tires. I shall not discuss the advantages or disadvantages of pneumatic tires from a construction standpoint, but as regards their use for protecting roads it seems that pneumatic tires are certainly very much to be preferred to any other type of tire. It is our intention to elaborate upon all of these tests. We expect to include in the tests different types of pneumatic tire and different unsprung weights and to investigate some of the special wheels, such as cushion or spring wheels.

The road engineer is able to build an excellent road if he has proper funds and materials, but it should be the duty of automotive engineers to design trucks so that the road engineer can build economically a road that will stand the loads and punishment of truck traffic, without undue expense. It would be very helpful to the road engineering profession if the representatives of this Society would make it their duty to watch road conditions, to aid the road engineer in governing the forces that are being applied to roads and to help create a sentiment that would discourage the abuse of roads.

[1]Senior testing engineer, Bureau of Public Roads, Department of Agriculture, Washington.

WATER POWER

IN the West, where 70 per cent of the water power of this country lies, water power is known and appreciated. Here in the East we have a different problem. Conservation here must come by the development of such water powers as we have and combining them with steam plants economically operated and the product turned into a great trunk line system which will furnish power for the whole manufacturing district or zone. Twenty-five years will see the elimination of steam power in the zone from Boston to Washington and for 150 miles inland from the coast. Only by such a twentieth century method of furnishing power by wholesale can the manufacturers of this zone hope to compete with those of Europe and other countries where water power development is being rushed to conserve exhaustible fuel supplies.—*Bulletin of the Water Power League of America.*

FARM AND COMMUNITY

THE value of farm property is 51 per cent of all the property of industry in our entire country, approximating $51,000,000,000. The unit which affects the lives of the people most directly is not the state, nor the county, nor the city. It is the community. This unit is described by lines within which people are associated together for material and social welfare. That unit developed out of the needs of the times, when originally the farmer tilled the soil.—Governor S. R. McKelvie.

Recent Advances in Aviation

By Col. Thurman H. Bane,[1] U. S. A.

Semi-Annual Meeting Address *Illustrated with* Photographs

THE object of my remarks is merely to familiarize you with some of the Air Service work that we have been doing at McCook Field. The Air Service was known as the Aviation Section of the Signal Corps before the war. It became too large to be a section of the Signal Corps; so, during the war there was a temporary organization known as the Air Service which was divided into a Bureau of Aircraft Production and a Department of Military Aeronautics. Later these were united under one head and there was a Director of the Air Service. But the Air Service, up to June 4, 1920, was a temporary organization and not a part of the Army. Unless the Army reorganization bill had been passed on June 4 the Air Service would have reverted, July 1, to the Aviation Section of the Signal Corps, which we would have considered a calamity. This bill now makes the Air Service a branch of the Army co-ordinate with the infantry, cavalry, field artillery and coast artillery. The Air Service is the third branch in size in the Army. The first branch is the infantry, then comes the field artillery. We feel that we are now on a more or less stable basis as a part of the Army.

The Lepere Reconnoissance Triplane

Verville Single-Seater Airplane Which Was Entered by the Air Service in the Gordon-Bennett Race

You are all probably familiar with the fight that has been raging for the last year for a separate Air Service. Most of us who fly, and who have been in this service since before the war, feel that the Air Service is a specialty that should not be developed as part of some other service. The development of it should not be entrusted to the Army and the Navy, not because we think they are not capable of handling it, but because we think they are basicly interested in other things and that the development of the air should be given to a separate organization. The Army and the Navy would undoubtedly develop observation aviation for their own uses; but that cannot be developed without pursuit and attack aviation. Pursuit aviation is where the individual in one plane very rapidly climbs at high speed, flies off by himself looking for trouble and drives the enemy out of the air. The two-seater observation airplanes could not be operated over a fleet, for example, unless the air could first be cleared of the enemy's pursuit aircraft, because they would be attacked and brought down. We feel that the pursuit and attack aviation should be developed by a separate branch of the service. I think that some day, perhaps, we will have such an organization. As it stands now, we are much better off than we ever have been; that is, we are a coordinated branch of the Army and are commissioned permanently in the Air Service.

Airplanes Developed During the War

The pursuit airplane developed by the Air Service is a Thomas Morse design with a speed of about 150 m.p.h. It can climb to a 20,000-ft. altitude in 20 min. It is very maneuverable, snappy and a single-seater. The aviator goes up alone, looking for trouble. Another type of pursuit airplane, made by the Ordnance Engineering Corporation, has about the same speed and climbing ability. Fifty of each are being put into production now. The Loening monoplane, developed during the war, is now being built by Mr. Loening. We have also an airplane in which we are now mounting a large engine for the purpose of competing for the Gordon-Bennett cup in France. This airplane will have a new 600-hp. engine and is expected to develop a ground speed of 185 m.p.h.

[1] M. S. A. E.—Chief of engineering division, Air Service, Dayton, Ohio.

MARTIN DAY BOMBING PLANE CONVERTED FOR COMMERCIAL PURPOSES

The DH-4 originally had the gasoline tank between the observer and the pilot. In the observation airplane, there should be good communication between the observer and the pilot. An observation airplane is used for flying over the enemy's lines and spotting artillery work.

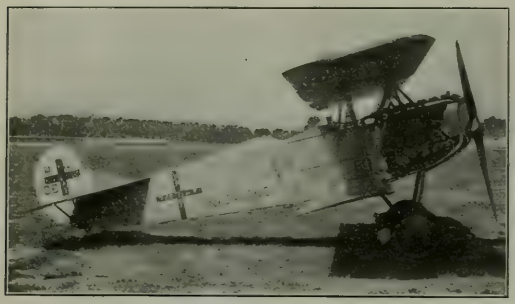
The XB-1A machine was started by President Vincent during the war. We are now having about 40 built for use on the Mexican Border. We are now patrolling the Mexican Border every day from Brownsville to San Diego. The Lepere triplane, built by the Packard Motor Car Co. during the war, is a very interesting type. It was far ahead of its time and was built and known as a surveillance airplane, for long-distance observation, to find out what the enemy does back of his lines. This plane flies high and for a long distance; it is a triplane, and has two Liberty engines on each side. The U S D-9A was built as a day bombardment machine. It carries 500 lb. of bombs under its wings and can reach an altitude of about 14,000 ft.

The short-distance night-bombardment airplane was built by the Martin company at Cleveland, during the war. We are building now 20 modified planes equipped with superchargers, so that they can climb much higher. The Martin bomber can carry a load of 500 lb. of bombs. These are controlled by the bomber, who rides in the nose of the machine. Through a glass he can see out to get his lead on the thing he intends to drop the bombs on. By a device like a typewriter, he can then select the bombs he wishes to drop and drop them from one side or the other, or all at once. The bombs that we now use weigh 25, 50, 100, 250, 500 and 1000 lb. We are now designing a 2000-lb. bomb. I suppose there is no limit to how large they may become; the tendency is to make them larger. Bombs also are carried inside an airplane with a trap inside of the fuselage.

TYPES OF BOMBS

We have an airplane that is built to fly low and shoot at troops on the ground which carries a 37-mm. cannon in an armored steel turret that is 3/16 in. thick on the side and ¼ in. thick on the bottom. It also carries eight Lewis machine-guns. A 37-mm. cannon can be mounted on a Martin bomber. It fires a sensitive high-explosive shell that will go off upon hitting the fabric of another airplane.

LEPERE ARMORED MACHINE DESIGNED FOR HARASSING TROOPS ON THE GROUND



THE FOKKER AIRPLANE

In the training plane built by Mr. Vought, of New York City, there is a hole in the upper wing so that in case of a wreck, the man in the front seat can climb out with a parachute on his back.

The German Fokker has a thick wing section; one strut and no wiring. It can be set up completely in about 20 min. The fuselage is constructed entirely of steel tubing welded at the joints. The wings are made of wood, in thick sections. We have learned much from the German Fokker. It is not very fast; our own machines are much faster. The Fokker makes about 115 m.p.h., but it is snappy and maneuverable. The engine-bed mounting is also made of steel tubing.

The German Roland is a very interesting type. It is made of ship-lap boarding and is very much the shape of a fish. It is a very nice-looking, streamline airplane and flies even better than the Fokker. The much-talked-of German Junker has a section about 2 ft. thick; it is a single-wing monoplane. Several of these are being operated as passenger ships in New York City and hold about eight people each.

The military Junker used at the battle front was a very interesting type and was the forerunner of the present commercial airplane. This is made of sheet aluminum, corrugated on the fuselage. The great advantage of this is that it can be left out in the weather, hangars are not necessary and the fire risk is practically eliminated. The Breguet is an interesting type of French construction. We are going thoroughly into metal construction in this country and I believe that in a short time it will entirely replace wood construction.

In reference to commercial aviation, we have the Martin bomber in which the fuselage is slightly modified so as to carry 12 passengers. The military value of this is evident. Passenger airplanes could be built so that they could be modified in time of war and made into bombing airplanes. This is an excellent airplane and flies very comfortably. It was built during the war to demonstrate that troops could be carried. The interior of the airplane is fitted with seats. I had the pleasure of flying this ship to Dayton from Indianapolis recently. It flies as well and as comfortably as any small airplane.

ENGINES

The Packard eight-cylinder engine of about 160 hp. was built this year. The Packard company built a series of three engines, an eight-cylinder, a small 12-cylinder of about 300 hp. and a large 12-cylinder which we hope will develop about 600 hp. The eight-cylinder engine has a carbureter on the bottom and the manifold goes up through the crankcase. Everything in this engine is accessible. In the small 12-cylinder engine the carbureter is also at the bottom. President Vincent, in this engine, has shown the advantage there is in having a designer learn to fly. We feel that a designer ought to know how to fly, as an aid to careful design. In the large 12-cylinder engine everything is also accessible. It is the same type of engine exactly and it shows a big improvement over the Liberty. The Liberty engine has the carbureter inside the V and the Packard large 12-cylinder

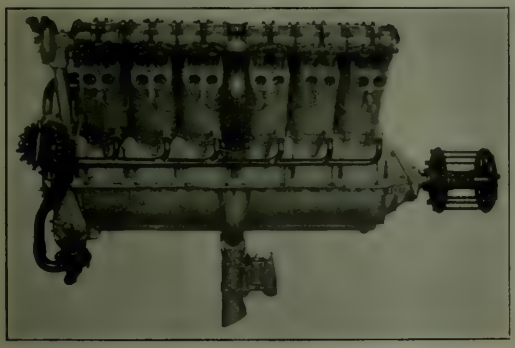
THE JUNKERS ALL-METAL INTERNALLY TRUSSED MONOPLANE

THE MARTIN AIRPLANE EQUIPPED WITH A 37-MM. CANNON

THE INTERIOR OF THE MARTIN COMMERCIAL BIPLANE SHOWING PASSENGER COMPARTMENT

engine has the carbureter underneath. The distributers are at the side, where they are accessible; on the Liberty engine the distributer is up against the fire wall.

I do not mean to detract from the evident merits of the Liberty engine. Men who fly and use the Liberty engine say that the Liberty-propelled planes are the most satisfactory and reliable aircraft we have ever had. A 650 to 700-hp. engine is now being built. It is an 18-cylinder engine in three banks. We hope to develop

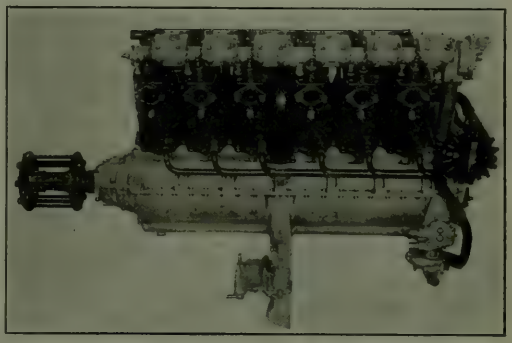


THE PACKARD 12-CYLINDER AIRCRAFT ENGINE EQUIPPED WITH FOUR VALVES PER CYLINDER

something out of it. It has a 5½-in. bore, a 6½-in. stroke and weighs about 2.2 lb. per hp. It is a step forward if high power is required. It has three magnetos. Everything is interchangeable. Any manifold can go any place; they are all alike. The same is true with the water manifolds.

A single-cylinder flexible laboratory engine, which is illustrated on page 22, is being built so that any reasonable-sized cylinder can be put in and any desired bore or stroke used. It is valuable for testing either air-cooled or water-cooled cylinders. An adjustable part in the center can be moved to get any desired length of stroke. It is a clever job and works out wonderfully well. We have supplied drawings to several manufacturers who are making them up for test purposes. The standard 300-hp. Hispano-Suiza engine is the best for pursuit purposes and we are supplying them in all pursuit airplanes.

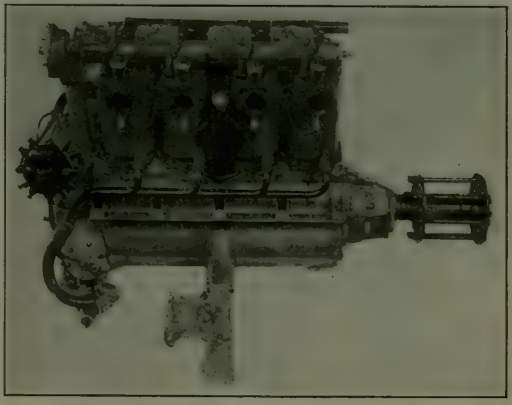
The Cannon Hispano engine of 300 hp. is provided with a 37-mm. automatic cannon, as shown on page 22. The engine is geared so that the cannon shoots through the propeller shaft. The crankcase differs from the ordinary construction, being split in a vertical plane. The nose of the cannon comes out through the propeller hub. The carbureter is underneath. The A.B.C. Dragon-Fly engine, which is illustrated on page 22, is supposed to develop 320 hp. We actually developed about 270 hp. with it. It is an air-cooled engine. We let several contracts this year for other air-cooled engines. We feel the air-cooled engine may be a very desirable engine for pursuit purposes. The J. W. Smith air-cooled engine, which is built in Pittsburgh, has a four-point cooling system in which air is projected on four points of the



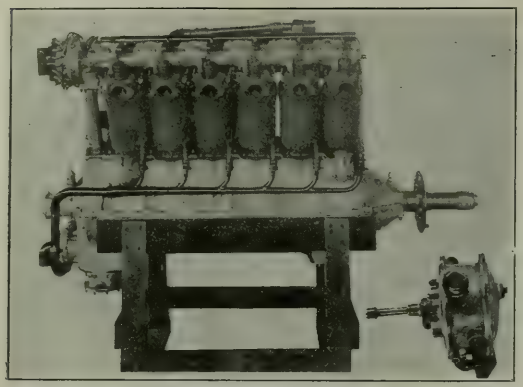
THE STANDARD 12-CYLINDER PACKARD AIRCRAFT ENGINE

cylinder. No air gets to the back of a cylinder in an ordinary air-cooled engine. A front view of the Smith engine is given on page 23.

We introduced an oil cleaner in the Liberty engine oil-pump. It is a small bucket something like that on a centrifugal separator, which throws the dirt out of the oil. The bucket whirls at high speed and throws all the dirt out. We ran an engine equipped with this device for about an hour and got a spoonful of Babbitt metal and refuse out. This oil cleaner assures us that the



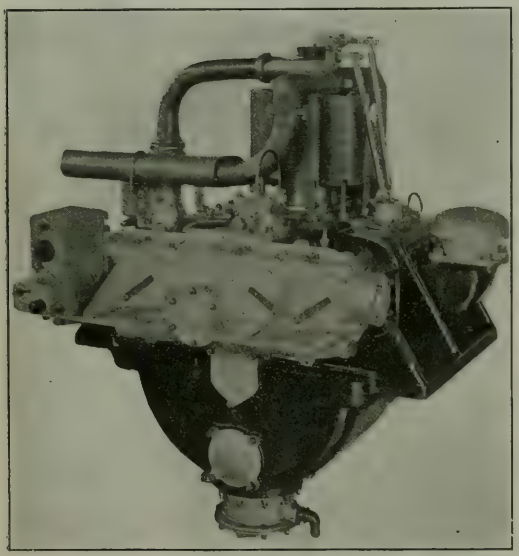
SIDE VIEW OF THE STANDARD EIGHT-CYLINDER PACKARD AIRCRAFT ENGINE



LIBERTY 12-CYLINDER AIRCRAFT ENGINE, THE CENTRIFUGAL OIL CLEANER WHICH WAS DEVELOPED BEING SHOWN IN THE INSERT

engine will always be clean. It lengthens the life of the engine very materially. It is a simple apparatus, as can be seen from the illustration and ought to be applicable to automobile engines.

We have a very light parachute pack, which makes flying as safe as walking on the ground. A wire goes over

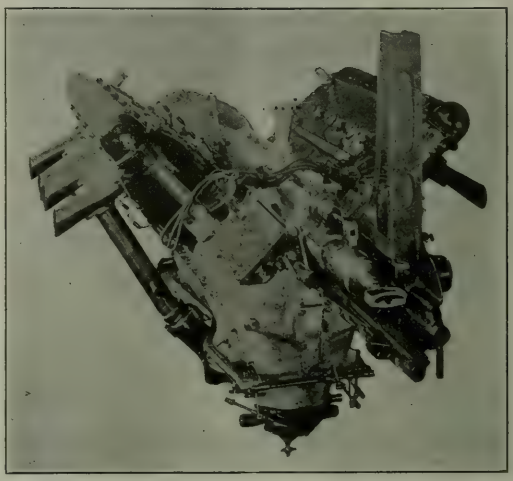


SINGLE CYLINDER ENGINE BASE USED FOR RESEARCH TESTS

the man's shoulder and has a ring in front which he pulls when ready to open the parachute after getting clear of the airplane. We have had over 100 jumps at McCook Field during the year. Recently several men jumped in one day down on the Mexican Border. Another development for this purpose is the seat pack, which takes the place of the pack on the back and serves as a cushion seat.

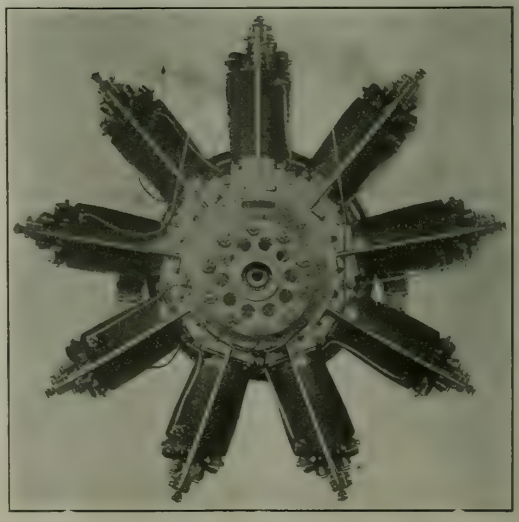
A new development is a Browning machine-gun, the latest 30-caliber and 50-caliber air gun. They can be used on pursuit airplanes. The ammunition includes the 30-caliber, the 50-caliber, and the 11-mm. The 11-mm. ammunition is incendiary. Airplane tanks have been set on fire by one shot from one of those 11-mm. shells.

A synchronizing outfit includes a machine-gun and a Nelson synchronizer. The latter is turned slowly and one shot is fired; then it is turned through 180 deg. and another shot is fired. It is revolved at 500 r.p.m. and makes a group on one side only, the disc is turned at

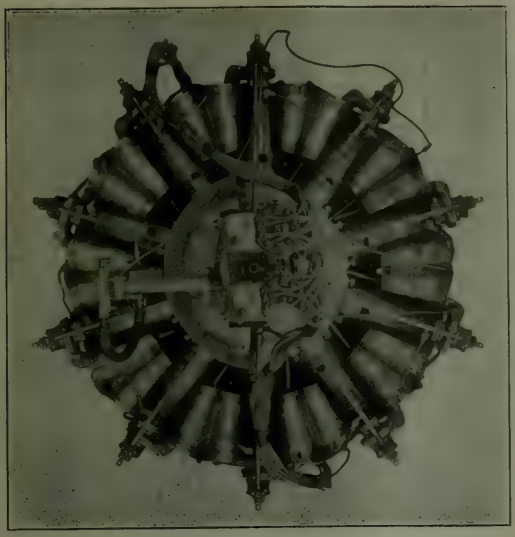


HISPANO-SUIZA ENGINE EQUIPPED WITH A 37-MM. CANNON FIRING THROUGH THE PROPELLER

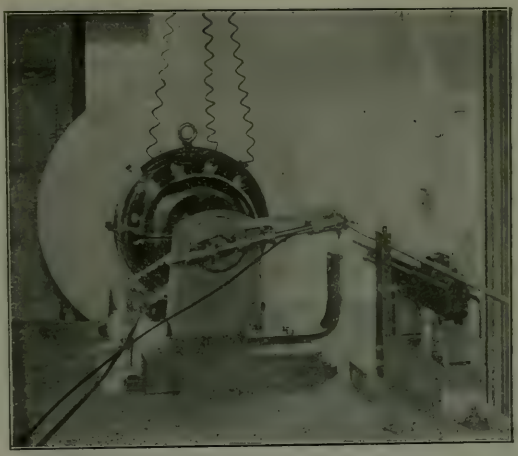
1000 r.p.m. and the group is there. This shows how far the bullets miss the propeller, and the enormous range of speed that the synchronizer must stand from zero to 2000 r.p.m. Still it only uses about 90 deg. of the arc and it has 180 deg. that it could use. The distribution



FRONT VIEW OF THE A.B.C. NINE-CYLINDER RADIAL AIRCRAFT ENGINE



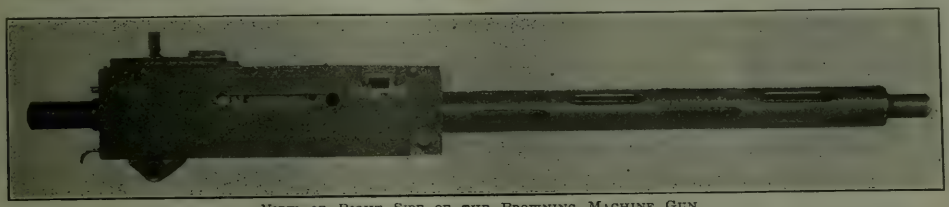
FRONT VIEW OF THE SMITH RADIAL AIR-COOLED AIRCRAFT ENGINE



APPARATUS FOR TESTING GUN SYNCHRONIZATION

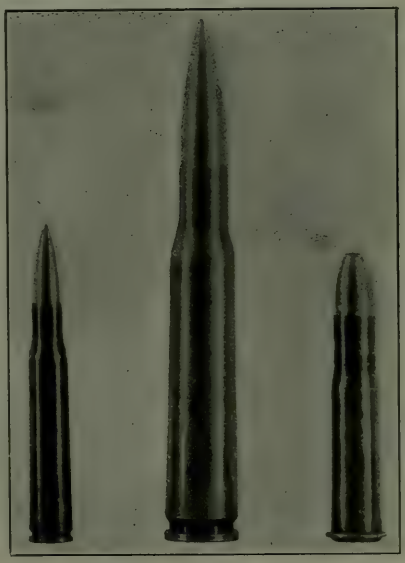
increases with the number of revolutions. We practically never have a shot that goes near the propeller.

At McCook Field we have a baggage car for the pur-



VIEW OF RIGHT SIDE OF THE BROWNING MACHINE GUN

BACK AND SEAT PARACHUTE PACKS



THE 30-CALIBRE, 11-MM. INCENDIARY AND 50-CALIBRE CARTRIDGES USED IN AIRPLANE ARMAMENT

PHOTOGRAPHIC TRUCK DEVELOPED FOR FIELD USE

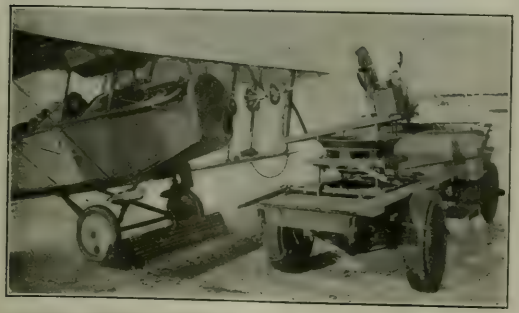
pose of installing photographic equipment and making drawings. In case of war we could equip baggage cars very quickly and supply them to the troops at the front. We have a camera weighing about 100 lb. and using plates. Originally we had difficulty in using films because the film could not be held steady. We are now able to use a type M-1 camera, which is the standard all-round camera for aviation purposes and uses films successfully thus saving considerable weight. The old French camera that we had weighed 140 lb. and has been abandoned. It could not be easily carried in an airplane.

In regard to starting apparatus, without a self-starter on an airplane to whirl the propeller it must be done by hand. On many planes it may not be desirable to have a self-starter; so, we have a portable starter that comes up and whirls the propeller and is then released by a clutch.

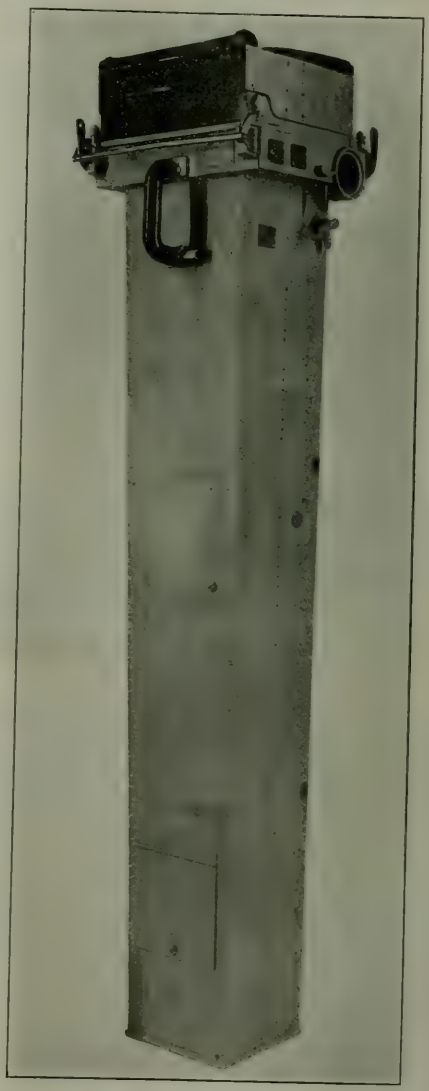
ARMORED AIRPLANES

The armored airplane previously mentioned has two Liberty 12-cylinder engines, eight Lewis machine-guns and a 37-mm. cannon. This airplane is designed to fly low, at 100-ft. altitude, and concentrates its fire on the ground. I honestly believe that a group of airplanes such as this could absolutely prevent an enemy from mobilizing on our borders. It is a very ferocious thing. It was designed and built at McCook Field and, from the time we started building it, only four months was required to complete it and put it into the air.

During the war Captain Lepere built a small armored airplane at the Packard plant which we also have in the air. In this airplane, which weighs about 8600 lb., the propeller is at the rear and each engine is entirely surrounded with armor. The radiator is located on top of the machine, so as to protect it from gun fire from the ground. The entire front half of this machine is armor and the rear half is veneer. We are building 10 of these airplanes for use on the Mexican Border. Gasoline is carried inside the armored nacelle.



AIRPLANE ENGINE STARTING DEVICE DEVELOPED AT MCCOOK FIELD



THE GAUMONT 120-CM. CAMERA
Complete Weight, lb. 61
Weight of Camera Body, lb. 39
Weight of Magazine Loaded, lb. 22
Height of Camera with Magazine, ft. 5
Plan Dimensions, in. 10½ x 13

For the fiscal year ended June 30, 1920, we had $4,000,000 to spend for experimental purposes at McCook

Field. Next year we will have $5,000,000, so this development can be continued. We asked for more money but with that much we can make some developments.

At the greater altitude it becomes desirable to have a propeller in which the pitch can be changed. In landing, the pitch can be reversed and the engine run wide open, thus providing a brake to force the airplane backward. A propeller which works that way is operated by a lever on the right-hand side of the cock-pit. In a demonstration of how this will shorten up the landing of an airplane, we measured many landings without using the reversible pitch propeller; the airplane ran 275 ft. along the ground before stopping. By changing the pitch the landing distance was cut down to 75 ft. An airplane can land in a very small field when it is equipped with a device of this nature.

Relation of Military and Commercial Aviation

In the military service, we feel that the commercial aviation can be developed side-by-side with military aviation. Anything that we develop for military purposes, for instance this variable-pitch propeller, is certainly valuable in commercial aviation. The same is true of large air transports carrying troops. They immediately become available for use in commercial aviation. The same is true of parachutes and, of course, the improvements in engine and airplane design are immediately available. Many believe there will not be much progress in commercial aviation for a number of years, but commercial aviation is bound to come.

The transport machine has made several non-stop flights to Washington from Dayton. The pilots are entirely enclosed. There are two windows in front that can be opened and they are habitually open, but the air flies by so fast that it does not enter the windows, although it provides some ventilation. This airplane weighs 10,000 lb. when completely loaded. On one of these airplanes we are now mounting a 3-in. cannon, which fires a 15-lb. projectile. We have fired this cannon on the ground; after the machine is assembled ready for the air, the cannon will be fired from the air. This transport is equipped with electric motor starters.

The airplane hospital ambulance may be useful from a commercial standpoint. A patient can be taken to a hospital quickly from an outlying district. The designer is Mr. Verville. This is an ordinary DH-4 machine remodeled to take two patients in stretchers. There are four such airplane ambulances in operation on the Mexican Border. We have in the Air Service more than 40 medical officers who are also pilots. The injured are given first-aid treatment, put in the airplane and rushed to the base. When they arrive, the ambulance is waiting and the injured men are taken to the hospital. It is not an impossible proposition or a dream to imagine that rapid transportation like that would be useful for emergency patients. If a man were taken with appendicitis down at Mission, Tex., he could be flown up to San Antonio in an hour and a half and operated on there; otherwise he would have to be operated on down there

Armored Machine Developed at McCook Field for Ground Attack Mounting Eight Lewis Machine Guns and a 37-Mm. Cannon

in the dirt and dust and would have small chance for his life. These airplanes will actually be used for that purpose.

In parachute jumping, we require each man to wear two packs, one on the chest and one on the back, so that if one parachute should break he could pull the string and use the other. The man, when getting ready to jump, stands out on a platform on the strut. Down on the Mexican Border recently, a man jumped from a 20,000-ft. altitude and it took him 17 min. to reach the ground. One method of leaving an airplane is called "lifting off." There is no jerk; the motion is very easy. It is like jumping from a 10-ft. embankment to land in a parachute. The men suffer no injury whatever. One man fell 300 ft. before he pulled the string. When asked why he delayed so long before pulling the string he said, "Well, I was afraid I would break it." Recently two men walked out to the end strut of an airplane, while in the air, and lifted off together. The rate of speed of the fall is from 16 to 24 ft. per sec.

A moving picture taken during General Mitchell's recent inspection of McCook Field shows a spotlight bullet as we call it, fired from an 11-mm. machine-gun. One shot into a tank destroys the fuselage of an airplane; it sets the leak-proof tank on fire. This bullet carries some fulminate and some magnesium ribbon inside which ignites as soon as the gun is fired, hits the gasoline on the edge of the tank and sets it on fire. Even our leak-proof tanks which will allow 50 bullets to be fired into them will not withstand this spotlight bullet.

The Utilization of Present Automotive Fuel[1]

By Frank C. Mock[2]

THE economic usefulness of the automobile and the motor truck lies in their ability to reach all places, travel at all speeds and overcome all road conditions. This has led to the development of a powerplant operating through a great range of speed and load. Conservation of the life of the mechanism and considerations of weight and vibration require that this powerplant be made up of multiples of relatively small working cylinders. These two considerations together require that the individual fuel charges be small and be fed in infinitesimally small periods of time. In the case of the ordinary passenger car engine the individual fuel charges vary in volume from that of a sphere of about 3/16-in. diameter for a full-load charge, to a volume much less than that with the engine idling. These charges must be delivered in 1/6 sec. at the lowest engine speed, or in 1/100 sec. at very high speed. In 32 years of intensive study and research but one method has been found of accomplishing this fuel feed with an accuracy which will give any sort of satisfactory operation. This method involves metering the fuel along with and under the same force as the air flow and delivering it to the cylinder either as a vapor or fine mist commingled with the air charge. Whatever drawbacks exist in the fuel system of our automotive engines today are not attributable to this principle, but to failure to function according to it.

Impossibility of Fuel Atomization

There are still some who believe that the failure to evaporate present gasoline in the intake systems of our engines is due to improper metering or insufficient atomization in the carbureter. The best inswer to this is that experiments show that this gasoline cannot possibly atomize at the temperatures and under the conditions of operation in many of our motor cars. If a measured quantity of this gasoline is placed in a receptacle with sufficient air at atmospheric pressure for complete combustion, at 100 deg. fahr. only about one-third of the fuel will be evaporated, and a temperature of 160 to 180 deg. fahr. will be required before the whole can possibly change into the vapor state. At the present time probably 90 per cent of the motor cars in use are operating with an intake manifold temperature below 120 deg. fahr. Under such conditions the fuel feeds to the cylinders irregularly and intermittently. To insure satisfactory operation under the requirements of changing load and speed it is usually necessary to increase the richness of mixture from 15 to 30 per cent and this practice is highly detrimental to many functions of the mechanism as well as a notable economic waste of fuel. It is somewhat difficult to maintain a vaporizing temperature of 160 to 180 deg. and this high temperature is objectionable for a number of reasons. The most frequent objection is that it will reduce the power of the engine, necessitating a 5 per cent larger and heavier powerplant. It becomes more difficult to cool the engine and to obtain adequate lubrication under heavy loads in hot weather. These high temperatures greatly increase the tendency of the fuel to detonate or knock, compelling the adoption of lower compression pressures with a resultant loss in fuel economy.

Vaporization is more readily accomplished under partial vacuum and this fact alone makes it possible to keep many of our motor cars and trucks in use today. As the throttle is closed, in the present system of engine control, the air charge to the engine is rarified, being reduced from atmospheric pressure at full load to about 6 lb. absolute at no load. This latter pressure is part air and part exhaust residue. The effect of this pressure drop upon the vaporization temperature may be illustrated by the typical case of decane which is a paraffine series gasoline component of about 360-deg. fahr. boiling point. The vapor of this element reaches a density of one-fiftenth that of atmospheric air at a barometric pressure of about 29.5 in. and at 109 deg. fahr. It would reach one-fifteenth the density of air at about 5 lb. absolute pressure, the idling charge condition of an engine, at between 70 and 80 deg. fahr. Thus, under ordinary conditions, the vaporization is much more complete at closed throttle. The limits of the application of vacuum are obvious; partial vacuum in the intake passage means rarification of the air charge and reduction of the engine power and application of the vacuum principle externally would require an extra expenditure of fuel for that purpose.

Mechanical Atomization at Low Temperatures

Experiments show that mechanical atomization without increase of temperature is effective when the fuel is sprayed directly into the cylinder or the intake valve port but is not effective under the ordinary system of supplying a number of cylinders from one common manifold. The fuel separates out of the air at the bends and turns of the manifold and adheres to its walls thereafter causing the same troubles of erratic feed to the cylinders experienced with ordinary systems under similarly low temperatures.

If the spray from the carbureter is directed upon a surface or hot-spot heated to a temperature near or above the end-point of the fuel, the already fine drops from the carbureter will be broken up into even smaller particles. It is possible to produce this condition with good engine operation at a mixture temperature of from 40 to 50 deg. fahr. below the temperature of complete vaporization of the fuel. This device seems to have the valuable characteristic of a natural and inherent temperature regulation and works out to a very simple structure without mechanical complication.

With fuel of the present end-point, the exhaust temperature is adequate even with the engine idling, but if the end-point should be raised, a condition will be reached

[1]From a paper presented at the meeting of the American Petroleum Institute, Washington, Nov. 17-19, 1920.

[2]M.S.A.E.—Research engineer, Stromberg Motor Devices Co., Chicago.

where the exhaust temperature at light loads will be too low for proper action and an external application of heat will become necessary.

About 30 per cent of the passenger cars and 5 per cent of the trucks operating today have partially effective means of heating the intake charge and give fair operation during eight or nine months of the year. Most of the larger passenger cars built in the last 18 months are provided with intake systems that give fairly good operation all the year round. Not all of their devices produce proper temperature regulation the year round, but sufficient advancement has been made to indicate that within a year or so we will have the problem whipped if the fuel stays as it now is. In motor boats much less advance has taken place in manifold heating. The tractor industry has for some time been trying to burn kerosene as fuel. While it is not safe to say that this has been fully worked out, nevertheless they have learned how to use gasoline efficiently.

The first and most important future fuel requirement of the automotive industry is stability of fuel characteristics. The automotive industry is so massive that it requires several years for a simple change like the heated intake manifold to become generally adopted. When we consider that many motor cars are used from five to seven years it can be readily seen that it would take nearly a decade for any general changes in engine construction to take place. The troubles encountered with casinghead gasoline in warm weather, and blends of high test gasoline and kerosene in cold weather, are minor instances of difficulty resulting from the variation in fuel quality.

The invention and general use of an ingredient which can be added to the present fuel to prevent detonation is of almost equal importance. This will permit more satisfactory operation with present compression and a development in the direction of higher compression pressures with a resultant gain in the fuel economy that can be obtained.

OIL PIPE LINES.[1]

THE oil pipe line is as fundamentally a part of the oil industry as the railroad is of most other American industries. First introduced about 56 years ago, it has so demonstrated its superiority as a means of carrying crude oil from the well to the refinery that it has largely superseded all others. This has made possible the building of refineries in or near the large consuming centers, rather than at the wells, which are usually remote from the centers of population.

The pipes for conveying the oil are laid on the surface of the ground, or at a depth varying from 18 in. to 3 ft. beneath the surface, and the main lines are generally 8 in. in diameter. The oil is forced through the pipes by means of pumps operated either by steam or by internal-combustion engines. The pump stations are located from 1½ to 90 miles apart, varying with the condition of the country through which the pipe lines extend, and the viscosity of the oil to be handled. Some of the larger pipe-line systems are hundreds of miles in length. It is estimated by the United States Geological Survey that the mileage of oil trunk lines in the United States today approximates 34,000, and that the gathering systems, which are a fundamental part of the trunk systems, aggregate about 11,500 miles in length, making a total of 45,500 miles. At the time most of the lines were constructed, the average cost per mile based on 8-in. pipe was about $6,500. The cost of the average pump station at that time varied from $130,000 to $250,000. The cost at present, on account of the increase in price of labor and materials, would be much in excess of these figures. The fixed investment in pipe lines corresponds closely with the actual cost of the property, and is estimated to be approximately $500,000,000.

The difference between the published pipe-line tariff rates and the railroad rates for shipping crude oil has always been so large that refiners and producers, even though they have no pipe-line systems of their own, cannot afford to ship by rail, except for comparatively short distances. The pipe-line rates, although greatly increased in recent years, are still much lower than those charged by the railroads for tank-car shipments.

The pipe specifications require that it be of a uniform quality of steel, that the threads be carefully made so as to make as perfect a union between joints as possible, and that it be capable of safely withstanding an internal pressure of 2000 lb. per sq. in. In some instances the pipes have been joined by pipe machines. Cases are on record where one pipe machine, operated by a gang of 28 men, has laid as much as 8700 ft. of 8-in. pipe in one day of 9 hr., whereas the usual accomplishment of an ordinary gang of 40 men is from 2500 to 4000 ft. per day.

The viscosity of the oil to be transported, and the topography of the country through which the pipe lines pass, are the factors determining the distance between pumping stations. The average distance in the Mid-Western and Eastern States is about 35 miles, while the average in California, where a relatively thick, viscous oil is handled, is about 12 miles, although stations are sometimes not more than a mile and a half apart, and in extreme cases are placed as much as 90 miles apart. The pumps are designed to deliver through an 8-in. pipe line approximately 30,000 bbl. of oil in 24 hr., working under a line pressure of 700 to 900 lb. per sq. in.

Practically all the pipe-line companies engaged in the transportation of petroleum have, in addition to their trunk lines, extensive systems of gathering lines. These are provided for the purpose of collecting the oil from the producers' tanks and running it to a tank farm or to some point where it can conveniently enter the main trunk lines. In some cases, however, these gathering systems are owned by the producing companies. As in the case of railroad operations, it is necessary to provide means for instant communication between different parts of a pipe-line system. For this reason it is usual for the pipe-line companies to own and operate their own telegraph and telephone systems.

[1]From an address delivered by C. P. Bowie at the convention of the Independent Oil Men's Association, Denver, Col., Sept. 30, 1920. Mr. Bowie is petroleum engineer, Bureau of Mines, Washington.

The Present Status of the Isolated Gas-Electric Generating Plant

By Charles Froesch[1]

Metropolitan Section Paper *Illustrated with* Photographs and Drawing

ELECTRICITY is unquestionably the most satisfactory medium used today for power and light, not only because it is safe, convenient and most flexible, but because it is beautifying and attractive. The low cost of fire insurance made possible by the use of

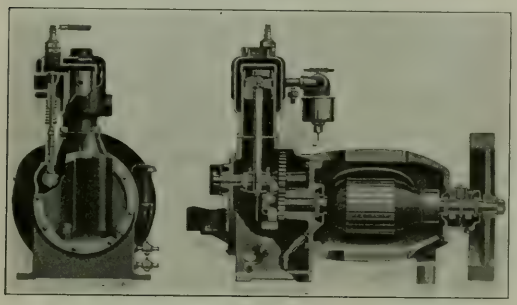


Fig. 1—End and Side Sectional Views of a 32-Volt 300-Watt Full Automatic Plant

electricity on the farm almost warrants its installation, this being 50 or 60 per cent of the cost of insurance when other lighting methods are employed. Electric light and power for the farm are meeting with constantly increasing popularity and, as only a comparatively small number of farms are electrified at present, the lighting-plant market is growing with surprising rapidity. To understand the magnitude of this field and its requirements, a brief survey of existing conditions is necessary. The following figures taken from a statistical report issued by the Department of Agriculture, while approximate at best, cannot be ignored.

There are today 6,400,000 farms in the United States having an average area of 140 acres. However, only 40 per cent of these have more than 100 acres of area. It would not be fair to judge the market for isolated plants by these farms only, because many farmers having less than 100 acres can well afford to buy a lighting plant, while many owners of larger farms cannot or would not. We can say conservatively that one-third of the smaller farms and four-fifths of the larger ones form the future market. This gives a total of 3,328,000 farms. However, we must deduct from this total a number of different plants already installed and farms supplied directly by central power stations. Estimating the total number of isolated electric plants made up to the present at 200,000, and the number of farms supplied with central-station current at 7 per cent of the total, approximately 2,580,000 farms are available as a market for the isolated gas-electric lighting plant. Farmers are most conservative and discriminating and speak and act from experience. It is my firm belief that when the usefulness and necessity of the isolated lighting plant shall have been fully proved, every one of these farms will be electrically lighted.

Adequate central-power-station development and service extension in the rural districts cannot be realized in the near future. The influx of people to the cities and the increase in cost of labor and material will keep the utilities companies busy with city problems for several years to come, leaving the field clear of serious competition for the isolated-electric-plant manufacturers. It is true that here and there some steps have been taken to install high-tension electric lines in the country, but in most cases this experiment has been costly to the ultimate consumer, current being generally furnished on a kilowatt-mile basis plus an additional fee for equipment depreciation. The above analysis does not include the possibilities of the use of lighting plants for schools, halls, stores, camps, yachts and the like, or the vast field offered through export.

A lighting plant is expected to give light whenever it is needed and at as low a cost as possible. When the low-voltage plant first appeared several years ago, it was a rather crude affair consisting of a generator, a switchboard and a set of storage batteries, all mounted on a wooden base which in turn was bolted wherever con-

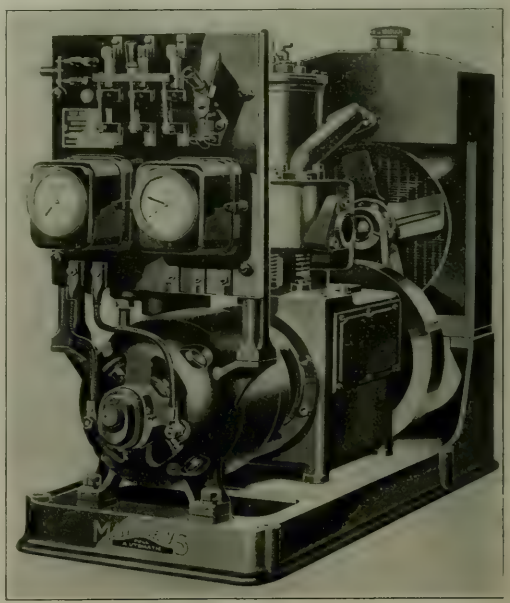


Fig. 2—A 1-Kw. Full Automatic Plant

[1]Jun. S. A. E.—Chief engineer, S. W. Merritt Co., New York City.

venient. It was invariably belt-driven by a gas engine bought separately and in most cases too large or too small to handle the generator load efficiently. The voltage regulation, if any, was poor, and the battery entirely too small; but in spite of this the equipment gave fairly good results in the hands of the layman and was decidedly better than kerosene or acetylene lamps. Latterly special engines and generators have been designed and storage batteries greatly improved as to life and reliability. The whole system has been specially adapted to the work to be done.

Common Types of Lighting Plant

Farm lighting plants can be classified in three groups:

(1) Full-automatic plants which, as their name implies, start and stop automatically when the battery is discharged or recharged respectively.
(2) Semi-automatic plants, which must be started by hand but stop automatically when the battery is fully recharged
(3) Assembled plants, which do not contain any automatic features and are in the majority of cases belt-driven

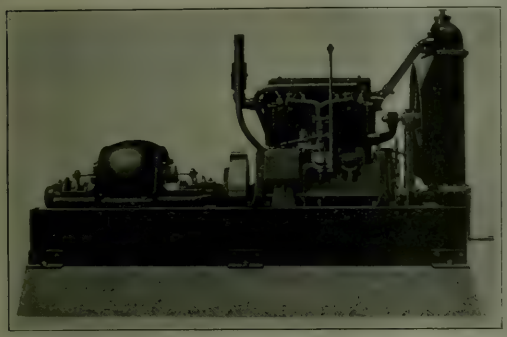


Fig. 3—A 5-Kw. 110-Volt Automatic Plant Which Is Used in Connection with a 108-Amp-Hr. Battery

Each one of these groups is made for 32 or 110-volt service. Some plants have been designed for 60-volt service, but their use is very limited owing to inability to secure motors and electrical appliances that can be run in conjunction with them. I understand that they are used exclusively for motion-picture apparatus.

Each one of the main groups of plants can be subdivided into three classes as follows:

(1) Plants furnishing power from the generator alone
(2) Plants furnishing power from the generator and the battery, or the battery alone
(3) Plants furnishing power from the battery and generator combined, or from the battery or the generator alone. The 32-volt semi-automatic plants furnishing power from the generator and the battery, or from the battery alone, are the best known plants today

The specifications issued by the lighting-plant section of the National Gas Engine Association regarding battery equipment and generator rating is interesting and worth noting. The following cell equipment is recommended for these plants:

(1) For 32-volt service, 16 cells of the lead type; or 25 cells of the Edison type

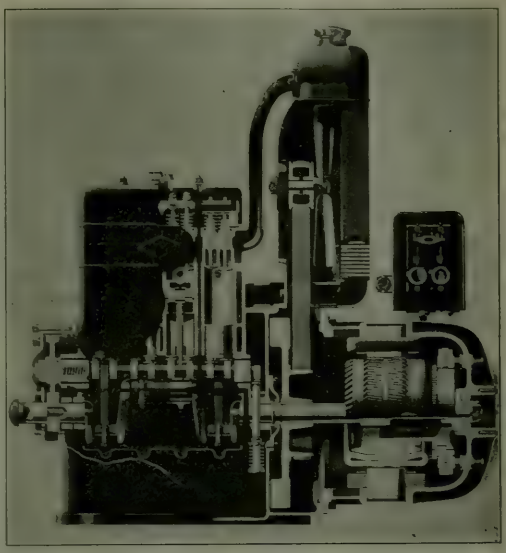


Fig. 4—Sectional View of a 110-Volt Full Automatic Plant Which Has a Full Pressure Oiling System and Does Not Use a Lighting Battery

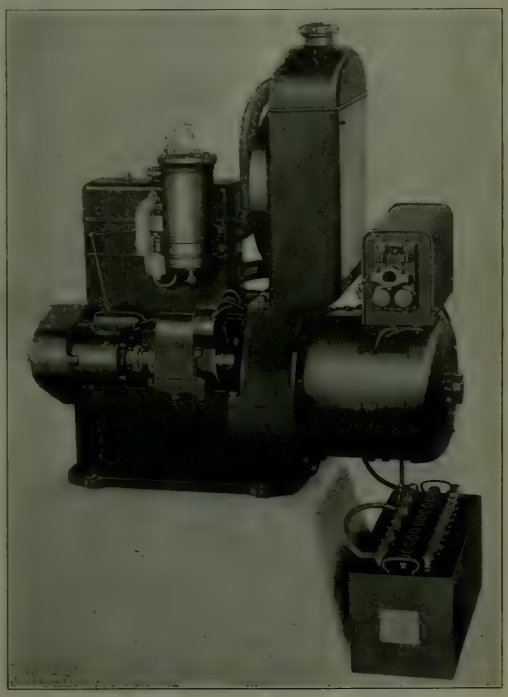


Fig. 5—Exterior Elevation of the Plant Illustrated in Fig. 4 Showing the 24-Volt Battery That Is Employed for Starting Purposes Only

(2) For 60-volt service, 32 cells of the lead type; or 50 cells of the Edison type
(3) For 110-volt service, 56 cells of the lead type; or 92 cells of the Edison type
(4) Generators are to be rated in watts, with a supplementary rating in amperes if desired
(5) For 32-volt service, the generator shall deliver 36 volts at full load. For 60-volt service, the generator shall deliver 72 volts at full load for continuous operation. For 110-volt service, the generator shall deliver 125 volts

The Consolidated Utilities Corporation manufactures a complete line of lighting plants ranging from 300 watts, for the 32-volt type, to 10 kw. for the 110-volt type. Its plants are known to the trade as the Matthews plant. They are made either with full-automatic or semi-automatic control. Fig. 1 on page 28 shows the 32-volt, 300-watt plant. It has a one-cylinder four-cycle gasoline engine of 2-in. bore and 3-in. stroke, developing 1 hp. at 1200 r.p.m. The generator has a maximum capacity of 450 watts. Two sizes of battery are furnished with this plant, a 55 amp-hr. glass-jar type, or a 70 amp-hr. enclosed-type rubber jar. Fig. 2 on page 28 shows the Matthews 1-kw. plant. It has a single-cylinder four-cycle gasoline engine of 3-in. stroke, developing 3½ hp. at 1250 r.p.m. The generator which is of the four-pole design has a capacity of 1000 watts for continuous operation. The battery capacity is 75 amp-hr. for the 32-volt sets, and 36 amp-hr. for the 110-volt sets. The full-automatic switchboard is shown. On the left is an ordinary ampere-hour meter and on the right a similar meter controlling the battery automatically. Immediately above the latter meter is the overload circuit-breaker, which disconnects the circuit as soon as the load increases above a safe limit.

Fig. 3 on page 29 shows one of the largest Matthews plants, made only for 110-volt service and used with a 108-amp-hr. battery. This plant is rated a 5 kw. The engine is a four-cylinder four-cycle overhead-valve type, having 3½-in. bore and 5-in. stroke and developing 20 hp. at 900 r.p.m., its rated speed. The generator is 110-volt for starting and lighting, with a separate booster commutator for charging the battery. It is driven by a fabric disc coupling. The switchboard is arranged for full-automatic control and has a starting rheostat, a separate voltmeter and an ammeter.

Fig. 4 on page 29 shows another full-automatic plant, made by the Kohler Co. It is a 110-volt plant without a lighting battery. The only battery used is a 24-volt set for starting purposes only. Depressing any light

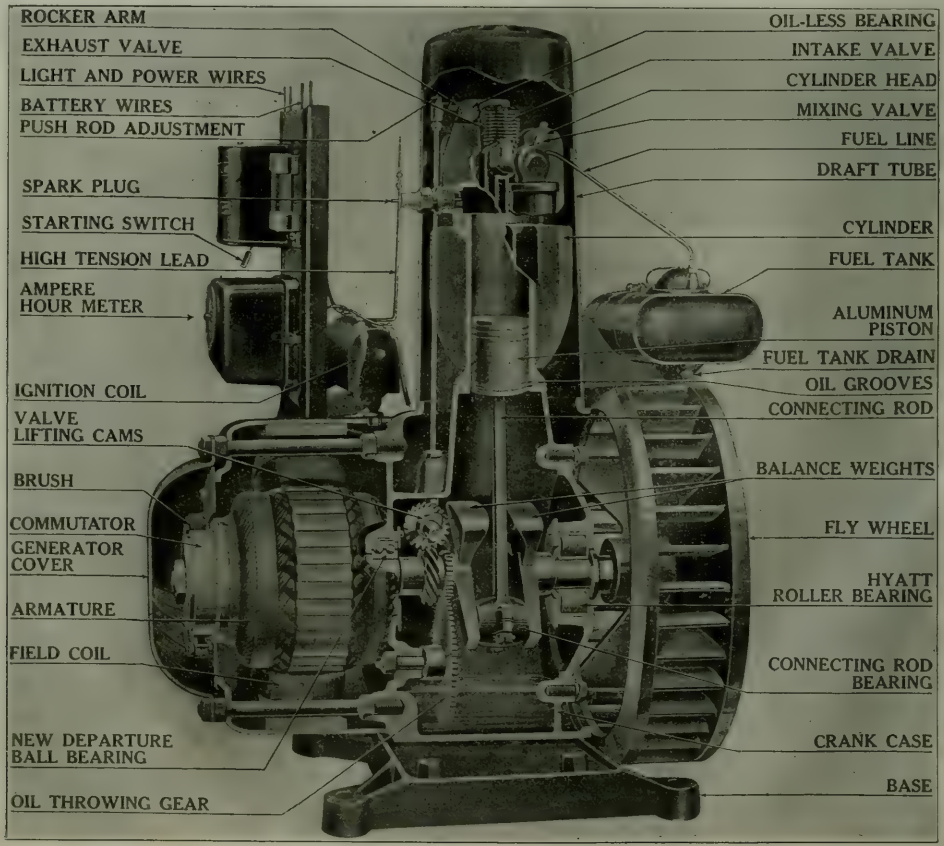


FIG. 6—A ¾-KW. 32-VOLT SEMI-AUTOMATIC PLANT

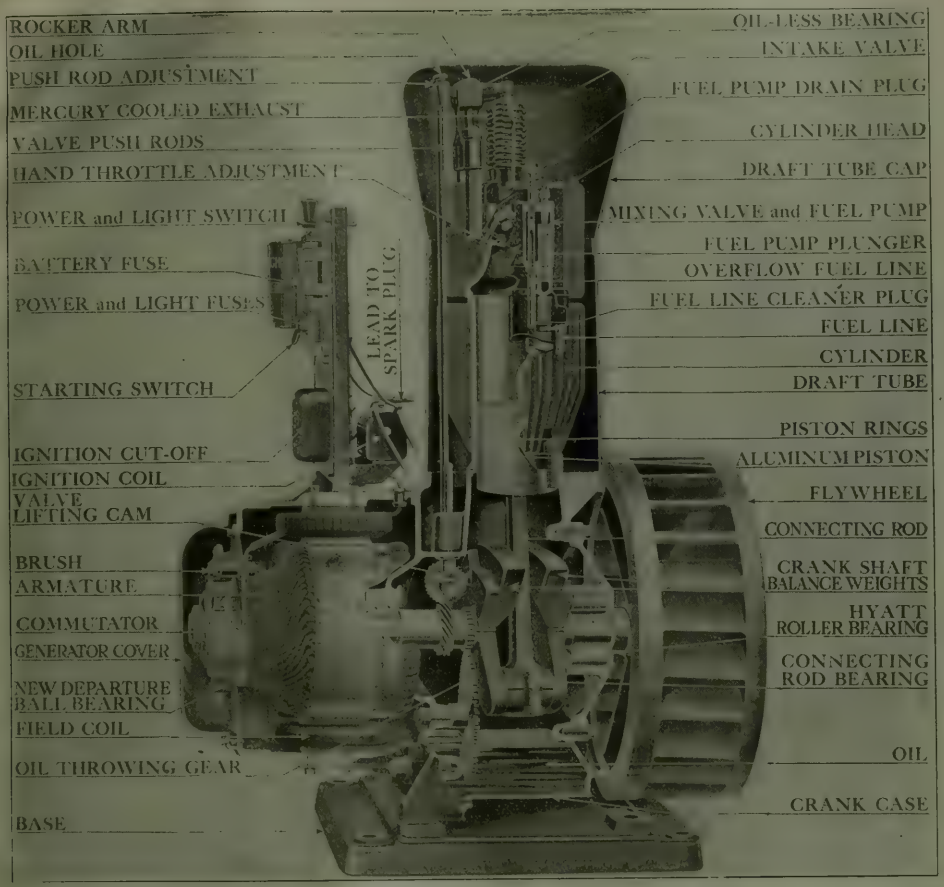


FIG. 7—A 3-KW. SYSTEM WHICH IS BUILT FOR 110-VOLT SERVICE ONLY

switch in the circuit automatically starts the plant; when the light goes out, the plant stops. It has a four-cylinder engine of 2-in. bore and 3-in. stroke, developing 3½ hp. at 1000 r.p.m. The engine follows standard automobile engine practice, having magneto ignition and a float-chamber carbureter with a vacuum feed system. This generator is rated at 1½-kw. and is compound wound. The switchboard provides complete automatic control of the plant; the controls are sealed in a box. Fig. 5 on page 29 shows the complete installation.

Fig. 6 shows the smallest of the Delco plants, which is seemingly one of the most popular. The illustration is self-explanatory and indicates almost every detail. All bearings are of the ball or roller type and the generator armature is overhung. This plant is of the 32-volt semi-automatic type and is used in conjunction with a storage battery of 160-amp-hr. capacity. It is rated at ¾ kw. It is an air-cooled plant, air being drawn through slots in the head cover and the cylinder, and expelled by a fan flywheel of the sirocco type. Lubrication is by splash from the gears. The crankshaft is counterbalanced.

Fig. 7 shows the largest size of Delco plant; it develops 3 kw. and is built for 110-volt service only. Its design and construction are similar to that of the smaller size. The Delco plants are made to run on either gasoline or kerosene. Fig 8 on page 32 shows a water system designed by the Delco engineers for use in conjunction with lighting units; a small electric motor operating a single-cylinder water-pump through a train of worm gears, in conjunction with a water tank; it is automatic in its operation, starting when the tank is empty and stopping when fully recharged. It works on the pressure principle.

Fig. 9 on page 32 shows the C-Y-C plant built by Carlton, Young & Catlin, Inc. It is a 1½-kw. 32-volt plant, comprising a single-cylinder four-cycle gas engine of 3¾-in. bore and 4-in. stroke, developing 5 hp. at 1200 r.p.m. It is equipped with a pulley for directly driving accessories. The generator is of the two-pole design and compound-wound. The switchboard control is of the semi-automatic type. The piston, rings, pin, connecting-rod, valves and springs of the engine are standard Ford parts. This ought to be an advantage when repair parts are needed.

Fig. 10 on page 33 shows a sectional view of the Lalley plant. It is a 32-volt semi-automatic plant of 1¼-kw.

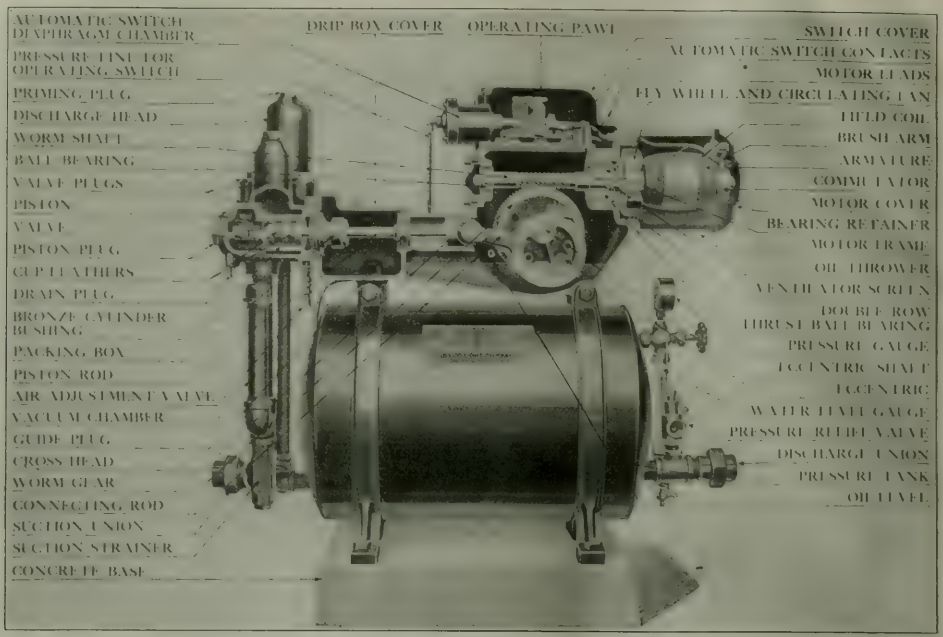


FIG. 8—AN AUTOMATIC WATER SYSTEM WHICH HAS BEEN DESIGNED FOR USE IN CONJUNCTION WITH THE LIGHTING UNITS ILLUSTRATED IN FIGS. 6 AND 7

capacity. The engine is of the single-cylinder water-cooled two-cycle type, having 2⅝-in. bore and 2-in. stroke. It is governed mechanically to run at a speed of 1800 r.p.m. and develops 2½ hp. at that speed. Lubrication is provided by mixing a certain amount of oil with the fuel which is stored in the base. The flywheel is located between the engine and the generator. The generator is of the standard four-pole design and driven by a flexible coupling. The battery has a capacity of 115 amp-hr. Fig. 11 is an outside view of the plant; and Fig. 12 gives a view of the complete installation.

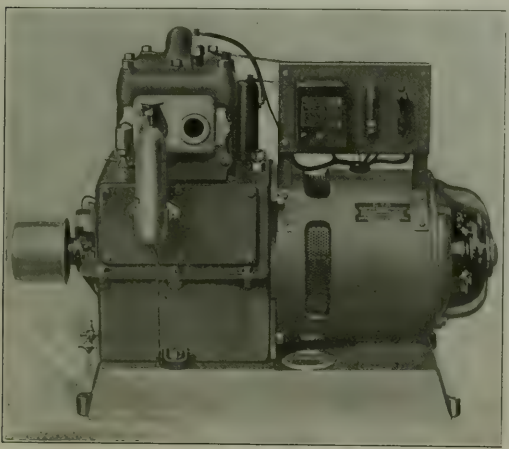


FIG. 9—A 1½-KW 32-VOLT PLANT EQUIPPED WITH A PULLEY FOR DRIVING ACCESSORIES BY A BELT

Figs. 13 and 14 on pages 34 and 35 show the Merritt plant, with which I am particularly well acquainted. The design follows conventional lines but, while there is nothing of startling originality about it, simplicity and compactness have been made keynotes. The capacity of this 32-volt plant is 1½ kw. at 1200 r.p.m., with an 1800-watt overload capacity for extended periods. It is a plant of the semi-automatic type furnishing power from the battery and generator combined, or from either battery or generator alone. It is composed of a single-cylinder engine of 3-in. bore and 4-in. stroke, direct-connected to a four-pole generator upon which is mounted the switchboard. The engine develops 3¼ b.hp. at its rated speed. This power is available at the pulley located at the generator end of the plant and can be used to drive any accessory or implement requiring up to 3 hp.

The cylinder of the engine is of the L-head type with detachable head; the bore is water-cooled and the head is air-cooled to permit a more complete vaporization of the lower-grade fuels with the lowest possible loss of volumetric efficiency. The compression ratio is 4.1 to 1. The valves, one inlet and one exhaust, have a clear diameter of 1⅜ in. and an 11/64-in. lift. The push-rods are steel stampings, 1 in. in diameter. The camshaft is located in a plane perpendicular to the crankshaft and directly above it. It is operated by a pair of helical gears. The crankshaft is of the bell-crank type and bored through to receive the armature shaft, which also clamps the flywheel against the shaft. The flywheel has 12 blades which form the cooling fan; these are cast integrally on the side facing the radiator. The design of these blades follows airplane-propeller practice. They draw the air through the generator and the radiator, which is located between the generator and the flywheel, and expel it radially through openings provided around

the flywheel housing. Cooling is by thermosyphon circulation, a cellular radiator is used and a small water-tank is located at the highest point of the return system to regulate the flow of water. The capacity of the cooling system is somewhat less than 2 gal.

Lubrication is furnished by a gear pump located in the bottom of the crankcase, which forms an oil tank of 1-gal. capacity. Oil is supplied under a pressure of 6 to 8 lb. per sq. in. to the crankshaft main bearings and through a hole drilled in the crankweb to the connecting-rod bearing. The upper connecting-rod bearing and cylinder wall are lubricated by the oil escaping from the main and lower connecting-rod bearings. The generator outboard bearing is lubricated by a self-contained ring-oiler following electric-motor practice.

Ignition is furnished by a tap from five cells of the battery and is of the jump-spark type. A roller timer is used in conjunction with a standard Ford ignition coil having its terminals located on the opposite end of the vibrator. The spark timing is fixed.

A ¾-in. nominal-size carbureter is used. This is merely a mixing-valve with automatic vacuum control for all loads. Fuel is sucked from the engine base, which at the same time forms the fuel tank and has a capacity of 3½ gal. This permits the operation of the

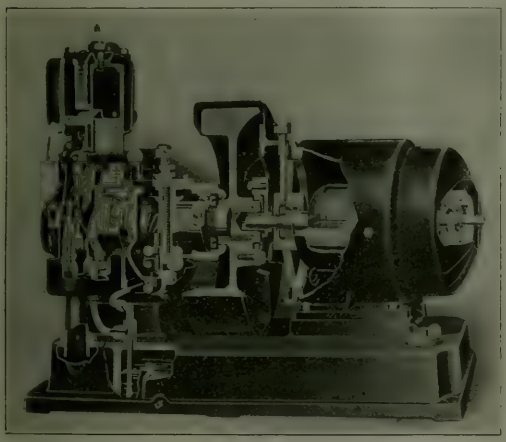


FIG. 10—ELEVATION, PARTLY IN SECTION, OF A SEMI-AUTOMATIC PLANT IN WHICH THE FLYWHEEL IS PLACED BETWEEN THE ENGINE AND THE GENERATOR AND THE FUEL IS STORED IN THE BASE

plant for about 13 to 14 hr. at the charging rate. Gasoline or kerosene is used. With the latter a small gasoline starting tank is provided. The engine speed is governed by a centrifugal governor that is very sensitive to speed variation.

The generator is of the four-pole design with four brushes. The field coils each have three independent windings which are, however, formed and taped together. The first is the shunt winding, the second is a small series winding used to maintain a constant voltage and the third is another series winding used only when the generator becomes a motor to crank the engine. The armature is of the standard drum-wound type and follows conventional practice.

On the switchboard are mounted the cutout or reverse current relay with its "start" and "stop" buttons; the ampere-hour meter, incorporating an automatic ignition switch which opens when the battery is fully recharged

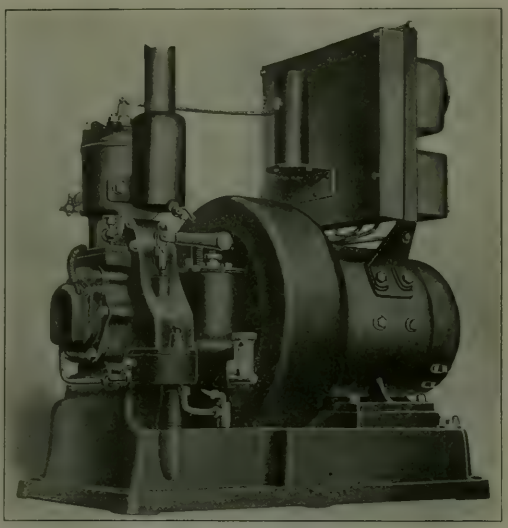


FIG. 11—AN EXTERIOR VIEW OF THE 1¼-KW. PLANT SHOWN IN FIG. 10

and thus stops the engine; a charging indicator; and the line switch with a 30-amp. fuse. The battery used has a capacity of 120-amp-hr. S.A.E. rating.

CHARACTERISTICS OF THE IDEAL FARM LIGHTING PLANT

It is most difficult to define the characteristics of an ideal plant of the type under discussion. For the sake of argument, let us assume a farm of 100 to 140 acres, analyze and tabulate its requirements as to both light and power and then devise the equipment. We can take the 25-watt lamp as the best for all-around use, as that seems to be the most popular size. The average lighting load per day on the farm is approximately as given in Table 1 on page 34.

The maximum lighting load per hour would occur when all lamps are used simultaneously; but, as this

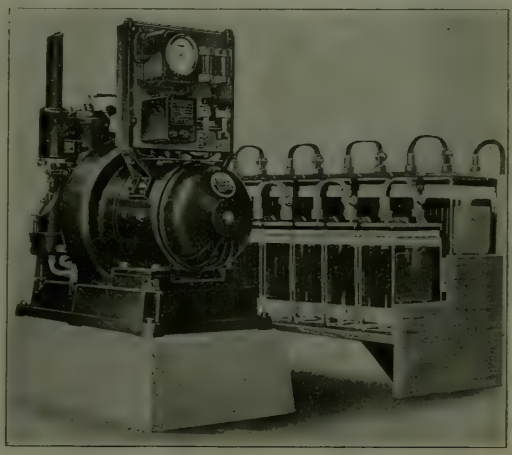


FIG. 12—ANOTHER EXTERIOR VIEW OF THE 32-VOLT SEMI-AUTOMATIC PLANT ILLUSTRATED IN FIGS. 10 AND 11 SHOWING THE STORAGE BATTERY IN PLACE

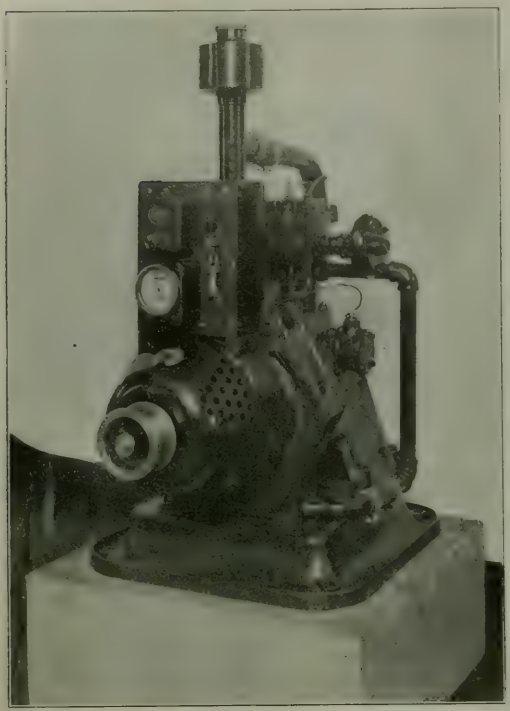


FIG. 13—A 1¼-KW. SEMI-AUTOMATIC PLANT CAPABLE OF FURNISHING CURRENT AT 32 VOLTS FROM THE BATTERY AND GENERATOR COMBINED OR INDEPENDENTLY FROM EITHER ONE

would seldom be the case, we can assume the average lighting load to be sixteen 25-watt lamps, or 400 watt-hr. For a modern farm of this size we can assume that the following appliances and motors are used. The power required is stated in Table 2.

No specific time can be assumed during which one or more of the accessories in Table 2 are used, and therefore this power load is a very variable factor. The power load values show that the lighting load is the smaller item.

In many instances and for different reasons, barns are located several hundred feet from the farm house. To handle these different loads efficiently the lighting plant should be set up where the mechanical and electrical loads are at a maximum, to keep transmission losses at a minimum. The plant must be of the 110-volt type, so that the drop of voltage between the plant and the most distant lamp or accessory will not be sufficient to decrease brilliancy or operative efficiency. Incidentally, this type will permit the use of smaller size wire and standard lamps and appliances. When it is realized that to carry 400 watts a distance of 150 ft. without abnormal voltage loss, No. 6 solid copper wire is required for the 32-volt system, the saving accomplished with the 110-volt installation deserves consideration. With the low-pressure system a drop of 4 volts decreases the lamp brilliancy 25 to 30 per cent.

The capacity of the plant should be sufficient to operate all of the accessories that might be used at the same time; also compromising with the charging load to secure the utmost economy. In Table 2 we would have a maximum power load of approximately 4 hp., representing two-thirds of the farm accessories plus the household appliances such as the electric iron, washing machine and vacuum cleaner. This would mean a 110-volt 22-amp. generator, or 2400-watt capacity at full load. With a charging rate of 4 amp. per hr., the charging load would be two-elevenths of full load.

It must be a battery plant because the lighting load is too small at times to be economically taken care of by the generator. In this instance the current consumption amounts to 400 watt-hr.; or, 400/110 equals 3.63 amp-hr. with the maximum load and 25/110 equals ¼ amp-hr. with the minimum. Battery manufacturers are of the opinion that, for economy and life, the maximum rate of discharge permissible should be slightly less than the rate of charge. This requirement is fulfilled.

We can consider the average life of a lighting storage battery to be 400 cycles. By the term cycle is meant a complete charge and discharge. Taking a battery of 40-amp-hr. capacity we actually have 30 amp-hr. available before a new cycle needs to be started, the remaining 10 amp-hr. being ample to crank the engine. This means that each cycle will last 30/3.63 or slightly more than eight days. The life of the battery under these conditions will be about eight and one-half years. In practice this would be a guess at best, for the reason that the lighting load is not uniform but changes with the seasons of the year. Another reason for a battery plant is that a battery is needed to crank the engine. Whether

TABLE 1—AVERAGE DAILY LIGHTING LOAD

Location	Number of 25-Watt Lamps	Service Hours per Day	Watt-Hours
Kitchen	1	3.0	75
Dining Room	2	2.0	100
Living Room	3	3.0	225
Three Bedrooms	3	0.5	40
Bathroom	1	1.0	25
Porch	1	1.0	25
Basement	1	0.5	15
Barns	5	2.0	250
Miscellaneous	5	1.0	125
Total	22	...	880

TABLE 2—POWER LOAD OF APPLIANCES AND MOTORS

Household	Power Required, Watt-hours
6-Lb. Iron	600
Toaster	500
Grill	500
Percolator	400
Washing Machine	300
Vacuum Cleaner	175
Sewing Machine	50

Farm in General	Power Required, hp.
Milking Machine	¼ to 1
Cream Separator	¼ to 1
Churn	¼ to 1
Refrigerator	¼ to 1
Water-pump	¼ to 1
Corn Sheller	¼ to 1
Bone Cutter	¼ to 1
Small Drilling Machine	¼ to 1
Forge Blower	¼ to 1
Grindstone	¼ to 1

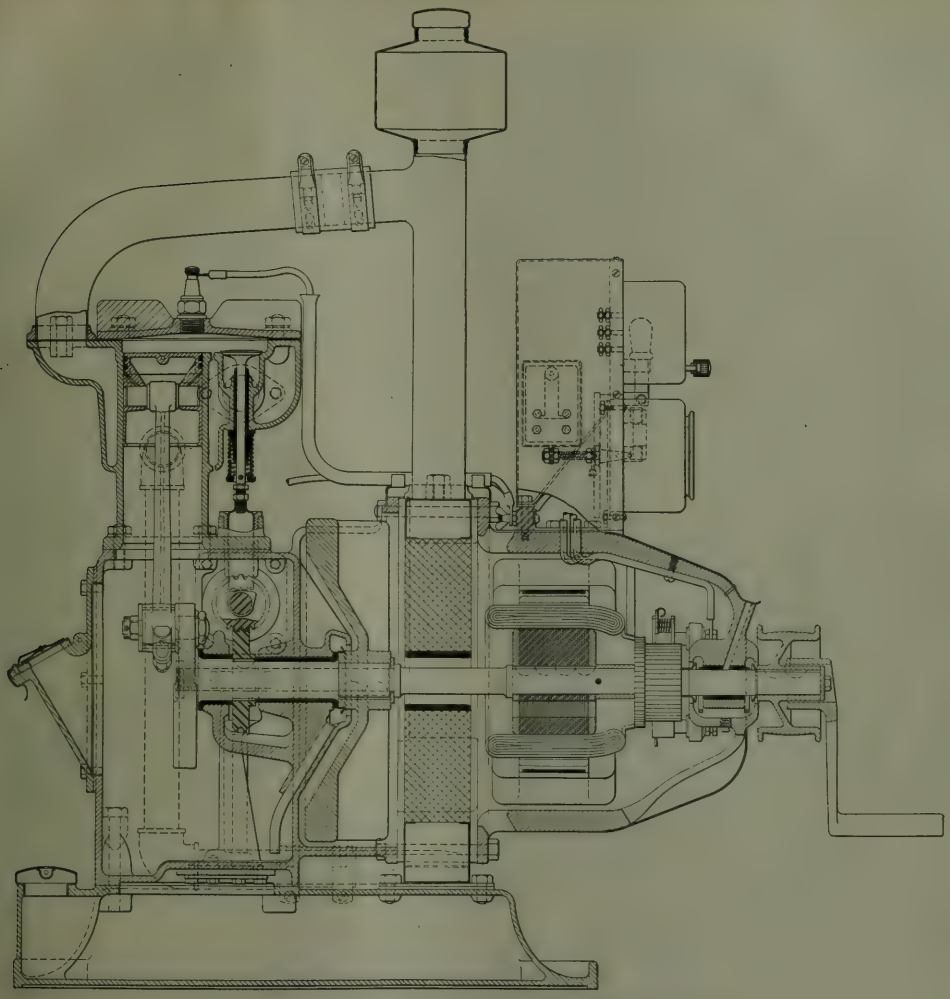


FIG. 14—SECTIONAL ELEVATION OF THE PLANT ILLUSTRATED IN FIG. 13

it is a 6 or a 12-volt starting battery or a 110-volt lighting battery it must be kept in operation just the same.

The plant must be fully automatic in its operation. It should start as soon as the battery reaches its lowest level and stop when it is fully recharged. It should also start automatically as soon as the load on the battery exceeds the charging rate and stop as soon as such loads are relieved. It must be designed to permit the use of the engine power to drive any needed accessories directly. It must be simple, reliable and fool-proof; a machine almost human in its operation. While the plant just described fulfills all the requirements of the average farm it can be made very flexible by increasing the size of the battery to suit conditions.

DESIGN FACTORS

The last phase to be dealt with is the one relating to the design of component parts. To be explained clearly, this subject must be divided into four parts; the engine, the generator, the switchboard and the battery.

A consideration of the design features of lighting-plant engines shows that no definite practice is adhered to. However, we find that the majority are of the four-cycle single-cylinder vertical type; four cylinders are used for the larger plants. Over 90 per cent of all farm lighting plants are direct-connected to the generator; belt-driven units are disappearing rapidly.

Regarding cylinder design, we find both the air and water-cooled type or a combination of the two. The latter is a happy compromise, as it permits a more complete vaporization of the mixture and a cooler-running engine. Water cooling is invariably of the thermosyphon type. With air cooling, a flywheel fan draws the air through the cylinder-head and cylinder and expels it outward. This cooling method seems to be limited to plants of 1000-watt capacity or less. There is no plausi-

ble reason for this and the advantages of air cooling certainly justify development for its use in larger plants. The main problem is to devise a cooling system adequate for any load at a constant speed; this would mean a fan varying its quantity output directly with the throttle opening. The I-head type of cylinder seems to be the most suitable, as it offers the least area of combustion-chamber wall to the flame of combustion. On the other hand, an L-head cylinder can be air-cooled satisfactorily and undoubtedly be made much simpler. The temperature of the walls should not exceed 325 deg. fahr. under full-load conditions; this entails heat-treatment of the material until the molecules assume a state of rest.

As regards valve design, we find almost every type. The poppet valve is used in every shape and form; the Knight sleeve valve, the rotary sleeve and the tapered rotary valve are used. Each of these valve mechanisms has advantages and drawbacks. The general trend seems to be more toward greater use of the poppet valve. It is the best-known type and gives the least trouble. Mushroom-type cams with flat-face followers are the rule when poppet valves are used.

In reference to cams, the company with which I am associated carried out experiments to determine the best valve-timing to suit the plant shown in Fig 13 on page 34. Two camshafts were made in an attempt to determine the proper valve-timing for maximum power at full load and at 1200 r.p.m. or 800 ft. piston speed per min. The first shaft had the following timing: Inlet opens 10 deg. late; exhaust opens 42 deg. early. Inlet closes 35 deg. late; exhaust closes 5 deg. late. The peak of the power curve was at about 1650 r.p.m. The second shaft was timed as follows: Inlet opens 6 deg. late; exhaust opens 40 deg. early. Inlet closes 30 deg. late; exhaust closes 3 deg. late. The peak of the power curve was at about 1475 r.p.m. With either shaft at 1200 r.p.m., the difference of power was very slight, but a greater fuel economy was obtained with the second shaft.

Lubrication in farm lighting plants is provided by splash or pressure. The splash system is used with ball or roller bearings and a low-pressure circulating system when bearings are plain. As in automobile practice, the pump is generally located in the bottom of the crankcase, which forms the oil-tank. A suggestive adaptation of the pressure circulation of oil, without using a pump, is to have the oil-tank separated from the crankcase but connected to it by a ball check valve or similar device, utilizing the compression of the air by the piston on its downward stroke to force the oil to the bearings. The amount of oil used by a lighting plant having a circulation pressure system is minute. In a 1000-hr. test made with our plant, the oil was never changed; the only thing done during the test was to add slightly over 1 qt. of fresh oil. This test covered a period of seven months and represents about three years of ordinary use on the farm. Upon analyzing this oil, we found that crankcase dilution amounted to about 30 per cent; nevertheless the total wear on all parts was hardly measurable.

The battery system is the prevailing type of ignition. However, most plants designed for export have a magneto. The reason for the use of a magneto is that batteries have to be shipped knocked down and are practically dead. So far as cost is concerned, the magneto compares favorably with the battery system, although the latter is somewhat cheaper.

A very interesting paper was presented by A. P. Young before the Institution of Automobile Engineers on the Process of Ignition, which states that the voltage which gives rise to the current in the short-circuited primary winding of a magneto is alternating, being produced by rotation of the armature; therefore, it is at a minimum at low speed, but increases in value with the speed. In the battery-coil ignition system, the voltage is direct and independent of the speed and is at all times equal to the battery voltage. This is the main fundamental difference between the two types of ignition apparatus.

The lighting-plant engine is essentially a constant-speed engine; therefore the battery system of ignition is the most suitable. Another advantage of this type is that its voltage is direct, which makes it possible to vary the duration of the spark to secure the best ignition of the charge. In the plant under consideration now the timing is set to allow the spark to cross the spark-plug points from 30 deg. before dead-center until 5 deg. after, or a spark duration of 35 deg. We found this gave the best results for power and economy, as a certain time is required to completely ignite every particle of gas within the cylinder.

Referring to the proper spark-plug position, I wish to substantiate the statements made by Captain Hallet that preignition can start from two oppositely located points in the combustion-chamber at the same time. When we first designed the cylinder-head, the spark-plug was located on the center line of the cylinder bore and, at full-load running, a disagreeable knock occurred. We reduced the compression ratio without results. Finally we moved the spark-plug toward the valve side, being careful to clear the bore of the cylinder, so that any escaping oil would not foul the plug. This eliminated the trouble.

Carbureters used on farm lighting-plant engines are of the well known float-chamber type or are plain mixing-valves based on the vacuum principle or operating in conjunction with a fuel-pump. Gasoline and kerosene are used. The float-chamber carbureter does not meet with the approval of the Fire Underwriters and will probably become obsolete as mixing-valves improve in design. They can be made automatic in operation and can handle any load with utmost economy. Their size can be so calculated as to hold the engine speed down without loss of power, in case the governor should fail to operate, thus averting serious breakdown.

Engine governors are of two kinds, mechanical and electromagnetic. The latter operate the throttle valve by a solenoid plunger, its movement being regulated by the rise and fall of the generator voltage.

Few manufacturers build their own generators. The four-pole design has almost monopolized the attention of American engineers because it seems to be the most adaptable type for the small sizes involved. Pole-pieces are laminated. The field coils have two or three separate windings, depending upon circumstances; a shunt winding, a series winding used only for starting purposes and sometimes a second small series winding to provide constant voltage irrespective of the load on the generator. In plants where no lighting battery is used, but only a small starting battery, the generator is duplex wound; that is, it has a special winding to charge the starting battery. While this tends to reduce the overall electrical efficiency of the generator, using power and light directly from the plant makes up for the loss through the use of the battery.

Real progress has been made lately toward the realization of a reliable fully automatic switchboard, but it is yet at best a very complicated and expensive piece of mechanism requiring an expert to keep it in running

order. Automatic control can be secured by two methods. One is based on the variation of the battery voltage or pressure; the other depends upon the actual capacity of the battery, its amperage or volume. The average switchboard of the semi-automatic type is very simple in construction and is generally composed of an ampere-hour meter registering the rate of charge and discharge and the condition of the battery at all times; a reverse-current relay combined with the starting switch, which keeps the main contacts together by electromagnetic action so long as the current flows from the generator to the battery and, when this action ceases, the contacts separate, the plant stops and the charging circuit is thus broken; and a line switch with a safety fuse. In some plants opening this switch eliminates all electrical load from the generator and all the engine power can be used as desired.

Storage Batteries

The storage battery is still considered the weakest part of the isolated plant. Much money has been spent by battery manufacturers to educate the buyer as to storage-battery construction, installation and care. The cells of a lighting battery are usually of the glass-jar type. Their capacity is determined by the work the battery has to perform. For lighting purposes only the battery should have a capacity of not less than 120 amp-hr. for the 32-volt system or 40 amp-hr. for the 110-volt service. When used for both power and light it should have a capacity of at least 160 amp-hr. for the 32-volt system or 60 amp-hr. for the 110-volt system. These ratings are according to S.A.E. standard; that is, they are based on intermittent discharge. Considerable difference of opinion still prevails as to which is the best battery-capacity rating, the S.A.E. standard or the 8-hr. straight discharge. While the former is better from the engineer's point of view, the latter is much simpler to express, although not so accurate. I merely record the facts and am at a loss to suggest any improvement.

The cost of a 110-volt set of batteries is approximately twice that of a 32-volt set of the same capacity. On the other hand, the loss of potential energy in the line circuit is much smaller in proportion with the 110-volt system. This calls for greater efficiency of the high-pressure type and, incidentally, when energy has to be carried some distance, the cost of the line for the 110-volt system allows a considerable saving over the line cost of the low-pressure type. Battery engineers have established the fact that the charging portion of the cycle of a lighting storage cell has the greatest influence on its life. Under normal working temperatures the positive plates disintegrate much more quickly than the negative plates. Deterioration within the positive plate is due to the loss of active material during the charging period and is known as sloughing. It is a gassing within the plates, producing small bubbles which result from the decomposition of the water of the electrolyte. In general, the slower the charge is, the better it is for the plates, although a high rate of charge is not harmful provided the temperature of the cell never surpasses 110 deg. fahr., which is the maximum charging temperature. It should be remembered also that a charging rate lower than normal causes sediment deposits and reduces the life of the battery. The same thing applies to an abnormally high rate of charge, but to a smaller extent. The best charging rate for the average lighting-battery set seems to be 12 to 14 amp. per hr. for a 32-volt 160-amp. set, and 4 to 5 amp. per hr. for a 110-volt 60-amp. set. As the generator furnishes constantly the same amount of watt-hours, the charge tapers off as the voltage rises.

So far as the best discharging rate is concerned, certain battery manufacturers claim that one-half the charging rate will allow the longest life of the battery. A high rate of discharge for short periods does not damage the battery, as seems to be the consensus of opinion, provided the normal section of the conductors is large enough to prevent overheating. It is not detrimental to discharge a battery completely so long as it is not allowed to remain in that condition. The best practice is to discharge the battery until its potential is just high enough to permit easy cranking of the generating unit. A lead-acid cell has a 2.2 to 2.3-volt e.m.f. when fully charged and a 1.7 to 1.75-volt e.m.f. when discharged.

Concerning the nickel-oxide battery more commonly known as the Edison type, this type of cell is used for farm lighting purposes in only a few instances. I understand that it will stand much abuse, but that it has a high charging rate and an overall efficiency of about 50 per cent. The Edison cell has a 1½-volt e.m.f. when fully charged and a 1-volt e.m.f. when discharged. This means that a greater number of cells are required for the same voltage; therefore, it is a more costly battery.

I hope I have made clear the importance of the farm lighting plant and its present position in the automotive industry. While I have not attempted to cover the subject from every angle, I have dealt with its most important questions and expressed my own opinions. In conclusion, I wish to emphasize that, while rapid strides have been made in the past, there still remains a great deal to accomplish as regards stability of design, reliability and economy.

THE DISCUSSION

H. Carlton:—Regarding the accessories which can be operated by the farm lighting plant, I believe they should be pushed by the farm lighting-plant manufacturers more than they have been in the past; also, that dealers should be persuaded to take on a full line of accessories and show the value of the electric generating plant from the standpoint of power as well as light.

H. D. Shamberg:—My experience has been mostly in the export field of the farm lighting business, which is growing very fast. The foreign customer usually prefers magneto-type ignition on any sort of internal-combustion engine. Perhaps this is due to prejudice against the battery-type ignition with the timer and coil, but I believe that the American automobiles which are selling so well abroad will overcome this prejudice, if it is a prejudice. The magneto-equipped plant is independent of the batteries and will operate even if the batteries become wholly disabled.

What is Mr. Froesch's opinion regarding the proper size of a plant for general use on a farm? It seems to me that if a small article like an electric iron requires 600 watts to operate it, a plant of say 750-watt generator-capacity would hardly be large enough for general farm utility; especially if more than one of these articles were used at a time and lights also were required simultaneously.

Charles Froesch:—I think the best size of plant for a farm is between 2 and 2½ kw. A plant of 1½-kw. capacity is a fairly good size, but it does not answer for the larger farms; it would be too small for general purposes. On the other hand, it would not be fair to design a plant to operate just one accessory or appliance that used 600 watts. The plant would be very inefficient, because a gas engine is not efficient when working under very light loads.

A MEMBER:—Are not most of the plants sold today of the smaller size?

MR. FROESCH:—Farmers are willing to buy a plant of larger size now. The tendency among them is to buy a larger plant even though it costs more. The larger plant has been demonstrated to them in a favorable light. Regarding the cost of the plant, the burning of two 25-watt lamps averages about 0.8 cent per hr.; using kerosene it amounts to 7 cents per kw., when kerosene is 18 cents per gal. With gasoline at 35 cents per gal. the price would be between 12 and 13 cents per kw.

W. H. YOUNG:—Why is there such a large difference in cost?

MR. FROESCH:—It depends upon what the price of fuel is per gallon.

A MEMBER:—Is depreciation included in that price of 12 to 13 cents per kw.?

MR. FROESCH:—No, that is simply the cost of the fuel. The battery is about the weakest link in the chain, as is apparent.

JOSEPH TRACY:—What is the power output of these plants per gallon of fuel?

MR. FROESCH:—About 500 watts; the consumption is about 1 qt. of fuel per hr. and the charging rate is 15 amp.

MR. TRACY:—You mentioned that some of the 75 different types of plant on the present market run without a battery; what is the approximate proportion?

MR. FROESCH:—Two plants are run without batteries; the remainder are all operated with batteries.

DR. RICHARD H. CUNNINGHAM:—Is the isolated plant adjustable with regard to the kind of fuel to be used?

MR. FROESCH:—When the machines leave the factory they are adjusted for gasoline, but there is an adjustment on the mixing-valve so that, by turning the valve, the plant will run on kerosene.

VOLTAGE REGULATION

C. M. MANLY:—I encountered the first isolated electric plants some 11 years ago when several companies were building 15 kw. and 25-kw. outfits for Army fortifications. They had to contend with the important matter of regulation. How closely is the voltage being regulated at present? The Government had very stringent specifications in connection with that between no load and full load. The tests that the generator and the entire outfit were put through in throwing them suddenly from full load to no load and back to full load were very severe. Voltage regulation was apparently the greatest trouble they were having at that time. Some companies seem to be producing outfits for commercial service that are perfectly satisfactory.

MR. FROESCH:—I am not in a position to throw very much light on that subject. On this little plant the only voltage regulator is a small series winding. I understand that some plants regulate their voltage with a solenoid plunger; that is, electromagnetically.

MR. MANLY:—How much voltage variation is there between no load and full load?

MR. FROESCH:—The voltage varies from 32 to 38 volts.

MR. MANLY:—How much voltage variation would there be on the 110-volt circuit? Have you built any 110-volt outfits?

MR. FROESCH:—No, we have not; but the difference must be greater because the National Gas Engine Association recommended that the plant must run to 125 volts at full load.

MR. CARLTON:—In building our isolated electric plants we have left off all governing arrangements; we have no special voltage control on the generator. We depend entirely upon the combination of the battery and the generator action to maintain the proper speed. We find that in this way we get approximately 2½ per cent voltage variation from no load to 25 per cent overload. In other words, it is a voltage variation that will barely give a flicker to the lights. We consider that this method has worked out well.

MR. FROESCH:—For export plants I advocate the use of a magneto because the battery is practically dead. However, if the total pressure of the battery is utilized there will be a sufficient potential to provide a spark for the engine ignition.

MICH E. TOEPEL:—Will the potential be sufficient for starting?

MR. FROESCH:—Yes.

MR. TOEPEL:—For what duration of time?

MR. FROESCH:—For a few short starts only. It depends upon the capacity of the battery.

MR. MANLY:—About the shipping of the batteries, what was the outcome of the proposition of shipping storage-battery plates fully charged and dry?

MR. FROESCH:—Some manufacturers did that, but they found that as soon as the plant was assembled the plates burst.

CARL F. SCOTT:—The great factor in the development of isolated plants was the tungsten lamp. It reduced the energy required to an extent that made possible a great amount of lighting from a very small engine and generator. A second great factor in pushing the business among farmers was the stress placed on "power" rather than on "lighting" features, because the possibilities are enormously increased by the use of power on the farm, as compared with the use of the light alone in the farmhouse.

With the larger plants, in connection with the increased cost of operation, is there not a tendency toward 110-volt plants that have only a starting battery and get along without a large storage battery? Have we realized the possibilities of increasing the speed, decreasing the cost and increasing the efficiency? Is the time coming when these plants can be run at full load, inside a room, so noiselessly that they would scarcely disturb a conversation? Regarding automatic control, is not the tendency toward a plant that starts up when the first device is operated and shuts down when the last device is turned off?

MR. FROESCH:—There are only two batteryless plants on the market now. They do not seem to be very popular with the farmers. One of the main troubles is that sometimes they start and sometimes they do not.

With regard to noise, lighting plants are continually being made quieter. This plant is somewhat noisy because it is hand-made and not a straight production job. We have made only about 17 machines of this type, and do not expect them to run very quietly. The fact that a plant has a higher speed does not decrease the cost of the plant. It must be made more accurately. It seems that the lower-speed plant prevails on the market. I believe in the high-speed plant, but it seems that the majority of the plants today run at 1200 r.p.m.

Regarding automatic control, very few such plants have been placed on the market. There is a tendency toward plants that start automatically, but sometimes they do not start, as I have said. A reliable automatic switchboard has not yet been designed, although it is the proper thing. Such a switchboard must be simple, because simplicity means reliability. It is hard to get, but we are coming to it. It must be remembered that this

type of installation is very young. We have been working hard on it. Previously such plants were simply makeshifts. No research work was done along this line until the last two years. A great many plants have been manufactured lately.

Controlling Devices

MR. SHAMBERG:—With reference to the full-automatic feature, it is a disadvantage to have a plant too completely automatic, because the owner is not likely to give the plant sufficient attention. The semi-automatic plant which is started merely by pressing a button can be designed with the starting switches at remote places. For instance, a second starting button can be put upstairs in a house, if the plant is in the basement.

MR. FROESCH:—I believe that one manufacturer puts out a meter which starts the plant automatically as soon as the load is greater than the rate of charge of the battery.

MR. CARLTON:—We watched the automatic system for some time and found that it involved considerable delicate apparatus which necessitated repeated inspection by persons who knew the apparatus. As a result, we produce a non-automatic plant that is started by the battery after pushing a button and stopped by a push-button also. We followed that practice to reduce the plant to the simplest form. We felt that it would be a safer plant to put into the hands of inexperienced persons; that there was a better chance of its being properly maintained. We do not see that it is necessary to put an automatic stopping device on an electric generating plant, any more than on an automobile starting and lighting equipment. The conditions are the same in every way.

MR. FROESCH:—The automatic feature of the ampere-hour meter is good. It is very reliable, and it eliminates the human element. It is possible that the farmer will run the plant too much and overcharge the battery.

MR. CARLTON:—The protection that we have installed is in limiting the amount of fuel. The operator can fill the tank full of kerosene, start up and let the plant run until the fuel is gone. We think that is a fairly safe feature. No expert inspection is necessary.

MR. FROESCH:—How can the exact condition of the battery be determined?

MR. CARLTON:—We believe the only proper way is by using an hydrometer.

MR. FROESCH:—We recommend that users examine the condition of the battery with an hydrometer monthly, and from that reading check up the ampere-hour meter. It can be done very easily.

W. S. BOULT:—One firm guarantees its meters to be electrically correct for one year. During the year, if anything happens to the meter, the customer need only take it off and send it to the factory. The same would apply at the end of the year; there is no charge for testing it.

FRED W. ANDREW:—We should understand that in charging the battery and discharging it there is always a loss. I had something to do with the Delco system in the early days and we took this loss into consideration. I think the instruction book said that the ampere-hour meter was to be checked up with the battery by using an hydrometer about once monthly. I fail to see how that condition could change.

MR. BOULT:—On the base of the ampere-hour meter we have a resistor that can be set for rates for overcharge of the battery ranging from 10 to 20 per cent.

MR. ANDREW:—One can charge the battery at a certain efficiency, but in discharging it one never gets out all that has been put in. Of course, the ampere-hour meter cannot take care of that ordinarily. Is there some device which automatically takes care of that discrepancy? As I see it, that must be set from an hydrometer reading at frequent periods.

MR. FROESCH:—The charging and discharging records from the ampere-hour meter are not the same. The needle travels 20 per cent more slowly on the charge than on the discharge. That is the reason we advise the monthly calibration of the meter.

E. J. BARNEY:—The resistor is a device used for keeping the ampere-hour meter in step with the battery so far as is possible but, over the wide range of load that it operates, there will be a slight error at about the end of a month. We take care of that by asking the user to charge the battery fully and to set the hand of the ampere-hour meter in the proper position once monthly.

A MEMBER:—I had my first intimate acquaintanceship with the isolated charging plant last summer. I found a battery in a country store that needed to be cleaned. The sediment had accumulated so that it came almost up to the bottom of the plates. Is the depth of the battery cells made sufficient to take all the sediment or, in general, must the battery be cleaned before the plate's life is entirely gone?

MR. FROESCH:—The battery should be inspected regularly.

MR. ANDREW:—The Koehler plant has a small four-cylinder engine and it operates by turning on or off whatever device one wants to use. The only battery used is a 24-volt battery for starting purposes, but this does not carry the load. Whether it operates well, I do not know.

In regard to ignition, you stated that the battery-ignition spark was on for 35 deg. Do you mean that the spark continued 35 deg.?

MR. FROESCH:—Exactly.

MR. ANDREW:—You do not mean that the build-up of the coil is for 35 deg.?

MR. FROESCH:—No, the duration of the spark is for 35 deg. in the plant.

MR. ANDREW:—How do you obtain that?

MR. FROESCH:—With a coil; it is a succession of sparks.

MR. ANDREW:—Do you use that vibrator continuously?

MR. FROESCH:—We use it for 35 deg.

MR. ANDREW:—Is it used like the old Ford vibrating coil?

MR. FROESCH:—Yes.

MR. ANDREW:—Do you have any trouble with the vibrator?

MR. FROESCH:—We have no trouble whatever.

MR. ANDREW:—Why is a water-cooled engine used for this work? When the Delco lighting system was first put out, we went over air-cooled and water-cooled engines very thoroughly. We concluded that a lighting system of this kind was likely to be installed in places where freezing might occur in winter. That is why Delco used an air-cooled engine, and why I am personally in favor of an air-cooled engine for that type of apparatus. If Mr. Froesch favors an air-cooled engine, why does he show a water-cooled engine?

MR. FROESCH:—Engineers are choosing the path of least resistance and such is the case in this instance. The air-cooled proposition is better, but it requires more research work.

MR. ANDREW:—I think there is no question that the air-cooled engine is about to come into its own, because of the scarcity of fuel and the fact that it can be run with greater efficiency than a water-cooled engine. I

have never been able to make up my mind that the 32-volt system is right. One can buy apparatus for the 110-volt system anywhere in the country.

The 32 and 110-Volt Systems Compared

Mr. Froesch:—The 32-volt system is pretty much standardized in the country now.

Mr. Andrew:—It surely is not standard in foreign countries. A number of Delco lighting plants were shipped to South Africa. Battery supply houses are scarce there. That is one of the reasons exporters prefer a magneto on the engine.

Mr. Froesch:—The first plants made were 32-volt; they included only a plain generator, a set of batteries and a switchboard. Why the battery manufacturers who made the plant chose that voltage I do not know, but it was the most popular type at that time.

Mr. Andrew:—I am not particularly in favor of 110 volts, alternating current, but what are the objections to a 110-volt 60-cycle alternating-current system that is direct-connected to a gas engine?

Mr. Froesch:—I am not in a position to answer that question.

Mr. Shamberg:—I believe the reason for the 32-volt system is the initial cost. It requires only a 16-cell battery, whereas the 110-volt system requires a 56-cell battery. The latter would cost considerably more.

Mr. Andrew:—That is true, but batteries are not necessary. Should we or should we not use the 110-volt system?

Mr. Scott:—I agree with Mr. Andrew. A 20-hp. engine and starter, a battery and accessories can be bought for about $510. The system described here costs about $645. Why is it not possible to have a system capable of more than ½ kw. without batteries and without more than the most rudimentary type of switchboard? Two years ago I made a lighting system for a country house. I used an air-cooled motorcycle engine and a small generator. About 11 p. m. we would shut off the switch. It ran for two summers. I suppose it had intelligent care, compared to the ordinary powerplant maintenance on a farm. It cost about $150, but perhaps would have been too crude to meet the ideals of the modern farmer.

There seem to be distinct possibilities in a 110-volt 60-cycle alternating-current light and power system operated without a battery. Such an equipment would use an 1800-r.p.m. single-cylinder engine fitted with a starting motor, generator, battery and switch of about the type used in a Ford automibile, or even smaller. The entire combination of generator, starter, battery and switch for this car can be obtained today for about $85. Thus the starting and excitation features would be a small item in the total cost. Such a generator and starting battery would be ample for exciting the fields of the alternating-current generator, which would be of the synchronous type. The generator could be constructed at a lower cost than the present direct-current generators, and the equipment would have the advantage of utilizing standard 110-volt lamps and devices and standard small 110-volt alternating-current motors, which have been developed to a very great degree of efficiency for all classes of work.

The only problems then connected with this system would be those of voltage regulation and automatic control. With the separately excited field, the problem of voltage regulation for varying loads would be no greater than that experienced on an automobile lighting generator at varying speeds. Granted a reliable starting and stopping switch for putting the plant into service when the first device is turned on, and stopping it when the last light or motor is turned off, we have a system that should be materially lower in first cost than those now offered; one entirely lacking in the objectionable features of the large battery; one adapted to transmit power greater distances without too great a relative voltage drop; and one using devices applicable to any standard power service equipment. Farmers would be more ready to install such systems, because of a realization that when central-station power came to their district at a later time, a large part of their own electrical installation would still remain standard.

Mr. Young:—When generator sets are manufactured in quantities comparing with the production, for instance, of the Ford motor car, I think they can be produced at a much lower cost. The present price, however, is comparable with that of other apparatus built in the same quantity.

O. A. Ross:—Referring to the suggestion just made to employ 60-cycle alternating-current generators, it must be remembered that the field of these machines is separately excited by a direct current. For this reason, a direct-current generator or a storage battery would be required. In the latter case a generator would be required to charge the storage battery. It is necessary also to regulate the field current with any change of alternator load; this, of course, can be done automatically. It seems to me, however, that in place of simplifying, the use of alternating-current generators adds complications to the isolated electric-lighting plants under discussion.

Elmer H. Schwarz:—Probably those who have spoken in favor of doing away with the batteries have forgotten that the average farmer does not run his plant all the time; the battery is needed to supply lights when the generator is not running. In case of a shutdown of the gas engine, the batteries are in reserve. I think that is the main reason batteries are used. One of the possible explanations of a 32-volt system is that train lighting had come to 32 volts, after a try-out of 80 and 60-volt systems. On account of this experience, undoubtedly, the 32-volt system was found to be the most practicable, mainly, I suppose, from the standpoint of the storage battery.

Henry C. McBrair:—In reference to the alternating-current system, is it not a fact that the General Electric Co. built a compact three-phase machine, and a type "D" machine called a "compensator" which had a small combination generator and alternator for exciting it; but that it abandoned them about eight years ago, and then used a separately-excited direct-current machine, which required an extra-small generator on the end of the alternator? I should say that this would be too complicated a proposition for a farm.

Mr. Andrew:—I think Mr. McBrair has answered the question. It is not a very difficult matter to build a separately-excited generator of small size and constant speed which can be used for farm lighting. To make it fully automatic, it seems to me that the final article in this line would be an air-cooled engine with possibly a 110-volt 60-cycle alternating-current generator.

Mr. Barney:—How will the voltage regulation be provided for on the alternating-current unit that has been suggested? It will mean the addition of some complicated mechanism, such as a Tirrell regulator. Anyone acquainted with alternating-current machinery knows that such a regulator is used in powerplants for regulating purposes.

Joseph A. Anglada:—Farm lighting maintenance resolves itself into the same proposition that we have with automobiles. We buy an automobile and for perhaps the

first two months we take care of it regularly; during the second two or three months we devote less attention to it; finally we decide that the car needs no attention. With the farm lighting outfit, the farmer puts the machine down in the barn to avoid its noise. The farmer with the non-automatic outfit finds it troublesome to go out and shut the machine off. We know that the two-cycle engine is a cheap one to build. It seems to me that a 110-volt, automatic, non-battery system is what we shall use eventually, just as we have adopted simplicity in automobile construction.

MR. FROESCH:—The question regarding the use of the two-cycle engine for lighting plants is very logical but, if we wish to use the plant to charge the batteries and also have a sufficient capacity to operate small appliances, the charging load will be very small compared to the full load, and it is well known that with a two-cycle engine it is too severe. You must make it small, so that the charging load will be high enough to permit good scavenging of the cylinder.

MR. CARLTON:—With a 110-volt system or with any other system without a battery, how will night-light conditions be met, such as a few lights for all-night service or a bathroom light? Without the battery, we must keep the engine running all the time we want light. With a battery this is taken care of.

MR. ANDREW:—It is already taken care of. The machine has to run, it is true, but it can be shut off at any time, right in the house, and without having the battery system carry the load.

FUELS

H. H. BRAUTIGAM:—Will Mr. Froesch inform us regarding his fuel problem? We have not yet made a perfect-running kerosene engine in the automobile or in the marine field. In the automatic and isolated farm lighting systems, we have a semi-loaded condition. We can operate on fuels which cannot be used in the automobile field, such as kerosene. Will the different outfits that are being put upon the market to run on both gasoline and kerosene be successful in the long run, and will they give satisfaction to the purchasers? We know that kerosene requires special means for vaporization. We must contend with carbon in the cylinders, dirty spark-plugs and more or less unburned fuel going down past the piston and collecting in the base of the engine. Every lighting outfit on the market today is put out to run on gasoline. All claim, however, that the outfits can be run on kerosene. But this requires a different adjustment.

MR. FROESCH:—The Delco plants have been very successful in using kerosene for fuel during the last two years. We have been using kerosene to a great extent, and we have found less carbon deposit with it than with gasoline. The carbon deposit we had with kerosene was gumlike; what we had with gasoline was solid. I cannot explain readily why this happens. I have not had time to investigate it. But it is a fact that we find the plant will run more successfully on kerosene than it will on gasoline.

WILLIAM E. KEMP:—Our experience has been that under certain conditions kerosene can be used as successfully as gasoline. It is my opinion that the single-cylinder engines used for isolated electric generating plants most nearly approach an ideal condition, principally because we can use the heat generated by the engine to better advantage, and also avoid the difficulties usually encountered in multi-cylinder engines wherein long intake manifolds are needed.

I have done some experimental work with heavy fuels and have found that with thorough mechanical vaporization of the fuel by vacuum, aided by sufficient heat closely applied to the inlet port of engine and with the fuel nozzle located as closely as possible to the inlet, or approximately 6 to 8 in. from the combustion-chamber, kerosene develops more power and is more economical than gasoline. This result is undoubtedly due to utilizing the greater number of heat units contained in kerosene.

There are numerous methods of applying heat to the mixture but, where the design has permitted, we have invariably obtained a higher efficiency by using a form of intake manifold, integral with the exhaust, that has caused the heavier particles of fuel to be impinged and retained against hot surfaces, and also permitted the lighter particles to be carried to the combustion-chamber at a lower temperature, thereby decreasing the volumetric losses due to expansion.

H. W. SLAUSON:—The sales possibilities of these plants are not limited to the farm. I do not live on a farm. I pay 12 cents per kw. for electric light. If I could get it for 9 cents, I would consider buying one of these isolated plants. Many people in this country have summer homes where such plants can well be used; at the seashore, the mountains or on small private estates. We should have a name for a plant of this kind that is more comprehensive than "farm lighting plant" or "farm powerplant," one that indicates its possibilities as a producer of power and light for every kind of house or service situated too far distant from the main power-current source. Regarding the power take-off on this particular plant, are there many conditions where it is better to use the power take-off than an individual electric motor?

MR. FROESCH:—Whenever it is possible to use a direct power take-off, it is advisable because it is not necessary to use batteries. Battery efficiency is between 75 and 85 per cent, but is about 75 per cent in most cases. I advocate the use of batteries for light and for small household appliances such as electric irons, but whenever an electric motor is needed a power take-off is more economical if it can be used.

MR. BARNEY:—In sections producing natural gas, I think most farm lighting plants could be operated on natural gas. In West Virginia, Kansas and Oklahoma natural gas can be obtained at from 20 to 30 cents per 1000 cu. ft. The average unit might, I think, be expected to deliver between 25 and 30 kw-hr. per 1000 cu. ft. That would cut down the operating expense.

E. FAVARY:—Does Mr. Froesch recommend any changes in the design of the engine when kerosene is used as fuel?

MR. FROESCH:—The main feature in this engine which is different from the automobile engine is the use of a bell-crank type of shaft. The connecting-rod follows standard design and so does the remainder of the engine. The only difference probably in this engine between gasoline and kerosene for fuel is that the head is air-cooled, resulting in vaporization. I think it vaporizes kerosene just as well as it does gasoline.

SERVICE

G. W. WARD:—I have sold many farm lighting plants and recently have visited the factories of many different manufacturers. Service is one of the biggest problems that the farm lighting industry has to contend with. These plants are placed on farms where they will be stationary and it will not be easy to give them attention. It is well worth while to begin right now thinking along

that line. A plant must be as nearly fool-proof as possible. These plants are going into isolated places. They will be forced to function under all kinds of conditions. Last fall I traveled 700 miles through Maine and found many farmers who had installed isolated plants but gone back to kerosene lamps. Many of the plants were of good design; others were of the old belt-driven hand-regulated type. The trouble was that the plants had not been serviced and the men who had sold them had left the district. No one manufacturer was to blame; half a dozen different firms were responsible for the condition. Later I was told that the manufacturers could not afford to render service. I found the same problem in another locality. We must standardize. Service must mean a certain thing; today it does not in the minds of the distributor and dealer. If the isolated-plant manufacturers will agree on what constitutes service and what their guarantee is to be on a plant, stick to it and insist that dealers and distributors do the same, we will eventually have the condition of a distinct class of men servicing plants in rural communities. Then the big problem that is retarding the industry as much as any one thing will have been solved. Many dealers are obliged to give up the sale of isolated plants because attempting to keep the plants in operation would take away a large part of their income.

C. W. DEAN:—The chief trouble with farm lighting plants is that the majority of salesmen sell the farmer too small a plant for the work desired or required by the farmer. The salesmen, eager to make sales, will guarantee service for one year and guarantee other matters they will not be able to live up to. In other words, they guarantee the farmer an engineer for one year. The word service has been much abused. No manufacturer can sell an isolated electric plant for $645 and guarantee an engineer to maintain the plant for a year.

A full-automatic electric-lighting plant without batteries is impossible with present inventions. A full-automatic electric-lighting plant wth a starting battery only is possible, but it is not satisfactory at present. The addtional cost of copper for installation must be considered. It would cost practically as much to run one light as it would to run 10 lights. The engine would be running to use one light just the same as it would for several lights. This would require starting up the plant often, waste fuel and use the automatic electric starting devices beyond their capacity or guarantee. It is no more possible to have a full-automatic electric-lighting plant without batteries, than it is to have a telephone, telegraph or wireless system without them. It is a known fact that all these systems have both batteries and generating sets.

Referring to a demonstration I saw in North Carolina, a plant had a 12-volt starting battery with a return wire run from each light back to the battery. When a light was turned on, the automatic cut-in would connect the generator with the battery and start the engine running. A 20-watt light was used and 15 of them were on one circuit. The negative wire was run the entire length of the lighting circuit to the main-line switchboard. There was a wire from each light to the positive side of the battery, thus making 15 return wires to the battery. I was the lowest bidder by $700 on a lighting plant for a building. I submitted proposals on a 3-kw. system with a 56-cell battery. One of my competitors submitted proposals on a 1½-kw. full-automatic plant, using a 12-volt starting battery.

MR. YOUNG:—Regarding the size of the isolated plant, I agree with Mr. Froesch that we should endeavor to make it 1½-kw., with an overload capacity so that certain extra appliances can be connected. The greatest difficulty in that respect has been that, with a small plant for lighting, the owner loads it up with curling irons, fans, smoothing irons and other additional electrical apparatus, and immediately gets into difficulties.

MR. BARNEY:—Concerning the life of the isolated plant, even more than five or six years of service can be expected of them. I know of some units that have been run between 17,000 and 20,000 hr. on test. Compared with the life of an automobile in actual running hours, this is very favorable. Allowing 10 hr. running time for a plant per week, the life of a plant should be much longer than five or six years, as Mr. Froesch's experience indicates.

MR. FROESCH:—The battery wears out in four or five years sometimes, but I have known instances where they have lasted 10 to 12 years. This depends largely on maintenance. With good care, the battery will last probably as long as the plant, but in the majority of cases the battery must be replaced before the plant.

LOW-TEMPERATURE DISTILLATION OF COAL

BY low-temperature distillation of bituminous coal is meant distillation at a temperature around 1000 deg. fahr. When distilling at this temperature a very small amount of gas of high calorific value is generated and a large quantity of tar with a small amount of ammonia. This process has been demonstrated on a practical scale by different investigators in this country and abroad. It has been definitely determined that from 20 to 30 gal. of tar can be obtained from 1 ton of bituminous coal, something like 12 lb. of ammonium sulphate and from 1 to 2 cu. ft. of gas and about 75 per cent of coke.

The tar from this process contains considerable quantities of engine fuel and creosotes. It has been estimated that it would be possible by the splitting up of this tar to obtain from 15 to 20 gal. of engine fuel per ton of coal. Investigations indicate that in a crude state this tar is worth in the neighborhood of 10 cents per gal.

The coke from this process would probably contain from 12 to 15 per cent of volatile matter which would contain most of the nitrogen originally in the coal. By gasifying this coke in the by-product gas producer, from 50 to 85 lb. of ammonium sulphate will be obtained per ton of coke gasified, and from 65 to 70 cu. ft. of gas having a calorific value in the neighborhood of 140 B.t.u.

The low-temperature process will yield by-products having a value of from $2 to $3 per ton of coal gasified. By gasifying the coke in the by-product gas producer the ammonia recovered will have a value of from $2 to $4 per ton of coal gasified, depending upon the amount recovered. In other words, by combining these two processes, by-products having a value of from $4 to $7 per ton of coal gasified can be obtained.

The low-temperature distillation of coal can be carried out in cylindrical retorts and discharged into the producers. A combination of the two processes will result in a mixed gas having a calorific value of about 150 B.t.u. per cu. ft. There are other advantages in the combination of the processes such as the simplification of the scrubbing of the producer gas due to the fact that 95 per cent of the tar comes off in the low-temperature distillation.

The market for the by-products obtained from these two processes is an increasing market. A large portion of the tar by-product can be used for engine fuel.—C. M. Garland in the *Journal of the American Institute of Electrical Engineers.*

Cooperation of the Automotive and Oil Industries[1]

By C. F. Kettering[2]

I AM delighted to have an opportunity of attending some sessions of this Institute. I had to leave the meeting this afternoon; I felt so corry for the petroleum industry after I heard the Doherty-Welch symposium about how hard up they are that I just got crying and had to leave the room. I understood that Welch finished the thing up by saying it is difficult to get blood out of a turnip, but that they are going to do it if possible. I have been wondering since who the turnip is. Representing some 8,000,000 users of petroleum products, and looking from the outside in, you know we have an idea as to who the turnip is.

Your president seems to have a little antipathy toward this curve business. I am here to tell you there are about 7,000,000 people outside of the petroleum industry who have never got onto the oil fellows' curves yet, and so we appreciate what he means when he says he does not understand curves. You have public opinion against you; rightfully, too. If the petroleum industry ran for president, it would be worse than it was this last time.

Here is the reason public opinion is against you; you talk about the newspaper fellows and all that, and what you say is true, but what has the petroleum industry done to educate the public as to what it is? If I were setting a little task for the petroleum industry to perform for the benefit of themselves and every consumer who drives an automobile, I would have you give out data not such as you gave out this afternoon, but say that for every gallon of oil you produce you only make a cent. I would not tell how many gallons you produce, though, because then you would get in jail sure. I would get the statistics out in a simple elementary form consistent with the imaginative ability of the average automobile driver, so that he could understand them, and every time that a man got his automobile filled at a filling station I would give him a receipt for the money that he paid on the back of which would be something about the oil industry. Now that is your newspaper. Your filling stations are your newspaper distributing agencies, and if you do not do that you will have all this government regulation, because everybody is against you, and I am going to tell you why before I get through. You deserve it.

In our town the filling stations range architecturally from Japanese pagodas to every other kind of thing in the world, and the owners will not hire any young fellows to run them, because they overflow the pumps and give you about half a pint more than you pay for. Anyone who is talking of the great scarcity of oil and then goes and looks at the filling stations that are established all over this land, can but wonder. "They must have a lot of money. They couldn't run them if they didn't." You just naturally feel that.

I feel a wonderful responsibility in representing 7,000,000 people here tonight, and I will try to tell you how one of the 7,000,000 feels, because the rest feel worse than I do, and because I know some of you fellows and that you are not as bad as they think you are.

The only cloud on the internal-combustion engine field today is the fuel supply. I think it was Mr. Doherty who said that he would guarantee for this generation, and the next generation and the next generation afterward that they will have an adequate supply of gasoline. Now, you know, the average user would like to know what gasoline is. That is a pretty serious question, and I am willing to bet that there is not a producer in this organization that uses the fuel which he sells in his own car. There are thousands of automobiles being laid up today because we cannot get them started. I get blame for that because we make self-starters, and it is not that at all. So I have a lot of trouble over this oil business.

The production of fuels today has a number of interesting phases. We have been increasing the demands for your product. You started this business out by making kerosene, and then you had to get some government regulations to keep you from putting all the gasoline into the kerosene and blowing the kitchen lamp up. Then the internal-combustion engine came along and took that by-product away from you, but they have never passed a rule the other way, to keep you from putting the gasoline in the kerosene and the Government still keeps these oil inspectors at your refineries. I was down at Baton Rouge at an oil refinery and a fellow was inspecting the kerosene to keep them from putting the gasoline in it. I said, "That is the funniest thing I ever heard." They said, "Oh, he never comes down. He has a colored fellow who stamps the numbers on the ends of the barrels."

High Fuel End-Points

To meet this fuel supply we have gradually increased the end-points of our fuel to the point where we have got into trouble. There are three fundamental problems that the automotive industry is facing. The first is the fact that as the gravity goes down, or the end-point goes up, we have more difficulty in vaporizing the fuel, which I think we can prove has nothing to do with the burning side of it; but it has much to do with getting the proper distribution in the cylinders. In other words, as the fuel is atomized it condenses on the sides of the manifolds and naturally runs along the edges, and the cylinders at the end will get more than those in the middle, where it is taken from the open manifold. We have the question of distribution; that is helped out by heating the manifolds, but not to the extent you think, as Dr. Dickinson has shown by moving pictures. The first big problem we have in the design of engines today is that of distribution. We realize just as well as you do that to raise the gravity of the fuel to where it used to be would not be economical from many standpoints. There is a common ground on which the distribution can be worked out satisfactorily. We have not exhausted all of our resources in the automotive industry yet.

[1]From an address delivered at the meeting of the American Petroleum Institute held at Washington, Nov. 17-19, 1920.

[2]M. S. A. E.—General Motors Research Corporation, Dayton, Ohio. Mr. Kettering was a delegate of Society and the National Automobile Chamber of Commerce at the meeting.

Following that comes another difficulty which is not generally known and which causes an immense amount of trouble, and that is the fact that the non-vaporized fuel which goes into the cylinder passes the piston-rings, and we have what is known as crankcase dilution; that is we thin the lubricating oil. When we thin the lubricating oil we dissolve it on the piston walls and we blow through some of the burned vapors and they condense and we get water in the bottom of the crankcase. The water freezes in the winter and we twist the shafts off. We have had some very learned men in the oil business who have said there is no such thing as crankcase dilution. Of course that settles it. But, nevertheless, we have it. In fact, the great difficulty we have is that people come around and say, "Why is it that I do not have to use any oil in my engine? It makes oil. I start out with it half full, and in two weeks it is full." That is really a serious question. The oil refiners say that that is because we do not fit our pistons and cylinders, and so on; part of which is true and part of which is not, because the best engines we make still have a large amount of crankcase dilution.

There are a few things that we must tell the public, things that the public ought to understand; why they have crankcase dilution, why they have this and that difficulty, and it is up to the automotive industry and you to tell them in a simple way so that they can understand. If people understood the real fuel problems and the real difficulties today, we could get them to do the things that are essential to overcome those difficulties to a certain degree. Now all they do is to berate the oil refiners for selling them bad fuel and blame us a little for not making our automobiles any too well. There is some truth in both of those accusations. Those two problems have to do with the end-point or the volatility of the fuel.

There is another thing which has to do with production. This afternoon as I listened to the oil men talk and assure us in their optimistic way about the wonderful supply of the future, they were all trusting to the Lord to get it for them. That is the thing which worried me, because I know a lot of them and that is the first time I ever knew them do that. The only thing they talked of in connection with the oil business was consumption. Production was all right; it was the consumption that was wrong. We were getting the production all right, but we were using too much of it.

As you bring the end-point of our fuels down we have another side to this question, which is the chemical side; and as you lower your gravity and you raise the end-points you are forcing the engine builder to lower his compression. As you force him to lower his compression the demand for fuel goes up because his engines run more inefficiently; the more inefficiently they run the more fuel he needs, and the more you must raise the end-points the more he has to lower his compression. It is just a question of time.

Chemical Phases

If we ever hope to solve this problem we must recognize that we are not interested in the millions of barrels of fuel produced per day, but in a much smaller matter than that, the molecular structure of the fuel and what we can do to help in that very important matter. It was about 300 years after the discovery of gunpowder before anybody had time to question whether that gunpowder and the gun were best adapted to each other; and they used to make the breeches very thick, and so forth. They were too busy shooting up people with what they had to inquire whether it was the best thing. I do not believe that there have been very many serious thoughts given to the question of the adaptability of our present fuel to the gas engine. It came in as a by-product, and it has been a buy-product ever since, and we have done the buying.

For only a few years have we been able to put indicators on gas-engine cylinders to measure waste. It was only a short time ago that they put indicators on the breeches of guns and found out that the growth of pressure with the old powder was just the reverse of what it ought to be, maximum pressure at the breech and minimum at the muzzle. Wonderful improvements have been made in artillery. The whole internal-combustion engine business is nothing but a species of projectile work in which we put the same bullet back in the gun every time we shoot it off.

With all due respect to the fact that your president took several very indirect slaps at the scientific side of things, if there is any one thing that is lacking in the petroleum industry today, it is intelligent science. I know the kind that he is talking about. He wants something that is seasoned a little bit. We believe in that, too. Nevertheless, we feel that there is a condition growing up here. We have talked about this to a great extent with the automotive engineers, and they have not bothered with the fuel question because all they have had to do was to build the engines. The fuel producers are not interested in the engine business; all they have to do is to sell the fuel. So this problem has been thrown out in the middle of the road, so to speak, and has been nobody's responsibility.

This organization, I think, is the first body in the history of the world that has made it possible for the automotive industry to talk about the fuel end of the matter. So that this is really a constructive meeting because it brings together our two wonderful industries. You say, "Our fuel must be all right, because people keep on buying it." I could not help but be amused this afternoon when one of the gentlemen spoke about the price of spring water which was 25 cents per qt., 15 miles from the source of supply. You know you do not have to drink spring water. You can get rain water if you want it. But it is altogether different with the fuel. Some of us live in such a modest way that we do not have to drink spring water. It is a fact that people have to take the fuel which is given to them without an understanding of why it is that the matter has got into the condition it is in now; so that for the first time, as I have said, we have the fuel industry brought into contact with the automotive industry.

Perhaps in the earlier days of your lives you debated in some country schoolhouse on which is the greatest civilizing influence in the world, the pen or the sword. I do not think that either of them has done very much. Horsepower has been the civilizing influence of the world. Just in proportion that men have been able to use power externally from themselves has civilization advanced; and the internal-combustion engine has been the greatest civilizing influence the world has ever had, for the reason that it is the first detached power unit we have had which has not had to run off a public service line, or something of that sort, and which a fellow could take out and do what he pleased with, load it up as he wanted to and run around over the country at will. We have supplied that which was mentioned this afternoon, the power to cultivate acres of ground, to produce food where otherwise it would have to be consumed by animals which furnished the horsepower. Petroleum, the liquid fuel side of the question, is the most important thing in the world today, and

the development of civilization, up or down, as it may go, will depend more upon the industry you represent than upon any other thing in the world. Abroad today the fuel question is a most serious one. In this country it has been more or less serious. On account of traffic conditions last year the coal question became serious, and we only realized to what a tremendous extent civilization depends upon horsepower. We look at an electric light and never think of the powerplant and the enormous amount of equipment back of it. We use power in various devices, our steamship lines, our railroads, our automobiles and our airplanes, all of which are today at the basis of future development and all civilizing work. This is something to be studied in the most serious way that men can study. Any amount of money that the automotive industry or the American Petroleum Institute may expend in solving apparently elementary problems connected with the internal-combustion engine will be repaid in the fruits of such research work manyfold.

Compression and the Fuel Problem

We have it on good authority that if we took 10 per cent of the heavier ends out of our fuel today, we could run more economically than we do now. We cannot burn the fuel sold at the average filling station today in a high-compression engine, such as is installed in an airplane. We cannot fly. It is almost impossible to get off the ground if we have to fill our fuel-tanks with ordinary automobile gasoline. The reason for it is that we get that awful knocking in the engine. With a compression of 125 lb. per sq. in., if we open the throttle to get two-thirds or three-quarters of the maximum power, the explosions become so intense that they just cave the piston-heads in. That, gentlemen, is the real fuel problem. We cannot raise the compression of our engines, because if we do, when we open the throttle wide, or when the engine gets a little dirty, the engine pounds so hard that it will fracture the porcelains in the spark-plugs, and will break down the bearings. When we lower the compression to the point where we can open the throttle wide and not subject the engine to undue strains, we work but very little of the time at that demand. In other words, the percentage of the total time that an automobile engine is asked for full power is very small; we must drive that engine along at 20 or 30 m.p.h., when the throttle is very nearly closed, and the compression is dropped down to maybe one-third or one-quarter of maximum; and we burn 90 per cent of all of our fuel in that very inefficient way.

If we can put the maximum compression up to, say, 120, 130, or even 140 lb., and not have the engine knock, or break up, we can practically double the efficiency of our engines at car speeds of 20 to 30 m.p.h. It is possible, by cooperation between this organization and the automotive industry, to increase the efficiency of our machines from 33 to 50 per cent.

Why do we not do that? Why can we not do that? When we take a full charge into a cylinder, or when we try to charge that cylinder at the present time, we have two things working against each other. In the first place, we have to add heat to vaporize the fuel; and from the very fact that we have to raise the temperature of the mixture to get vaporization for distribution purposes only, we reach another circumstance. Each fuel gravity carries with it another perfectly positive constant which is a function of two things; the compression to which the charge is subjected, and the temperature upon burning. If we do not pass the critical point for the given fuel, the engine runs very nicely. If we pass the critical point even slightly, the engine does not perform normally; we get a detonation not infrequently equal to the total explosion pressure of the engine, and sometimes very much greater. That is the basic fuel problem in the automotive industry; to keep down detonation.

If we can raise the compression of our engines, we can increase their economy, decrease crankcase oil dilution, improve distribution, and do other things that we cannot do now. We cannot do the things we want to do in the automobile engine until we get the proper fuel work done, and we have difficulty in getting the fuel work done before we get the proper engine. We must carry the movement in coordinated effort of the Petroleum Institute, the automotive industry and the chemical societies. We know enough today in very many ways to improve the present situation.

What we want in the automotive industry is a fuel and a lubricating oil that will give very good efficiency and obviate the necessity of cleaning the carbon out of the engine. I believe that with the right kind of cooperation that can be attained quickly. Carbon deposits contain a mixture that is nothing but a varnish, and acts in exactly the same manner. If that 5 or 10 per cent of binder is dissolved out, the rest of the carbon all goes out, and there is no trouble with carbonization. In other words, anything that is a varnish remover is a carbon remover. That is all there is to it. You can put any kind of a varnish remover in, if it is the right kind.

We have problems and I think we can write them down in a perfectly concrete way. We cannot solve them by some spectacular, skyrocket sort of a plan. We must get acquainted with each other and stop four-flushing. We will tell you what we are, and we think we know what you are.

CIVILIAN AVIATION

It is, indeed, interesting to note the very solid progress that has been made by foreign countries in the promotion of civilian aviation. Undoubtedly, the future will see air lines for passengers, mail and express matter running from Scandinavia to the very tip of South Africa and extending from all parts of Europe to the Orient. Such routes, once established, will save many weeks of time and wearisome travel over present-day modes of land and water locomotion. The fundamental principle behind the success of this infant industry, air transportation, must, of course, be government support. Once established, people throughout the world will accept aerial transportation much after the fashion as they accepted the railroad train despite the pious warnings that it would prove "an instrument of the devil." Today we are beginning to forget the 100 m.p.h. that was attained long ago in the air, and are interested in the fact that 200 m.p.h. has been passed, and that a speed of 500 m.p.h. is not an impossibility.

Major Schroeder proved, in his record-breaking altitude flight that, at about 30,000 ft. trade winds blow from west to east at the rate of 300 m.p.h., which means, at the proper altitude, we could be blown from San Francisco to New York City in 10 hr. Who would venture to say that at 50,000 ft. we might not find a wind blowing from east to west that would carry aircraft in its current at even a greater rate of speed?—Air Service News Letter.

Commercial Motor Boats and the Diesel Engine

By G. C. Davison[1]

Motor Boat Meeting Paper *Illustrated with* Photographs and Charts

THE owner of a commercial motor boat is always interested in the forms of power available for its propulsion. He must have a plant that is not only reliable in operation, but one which is safe, requires a minimum of attendance and is subject to a minimum cost of operation. At the present time the internal-com-

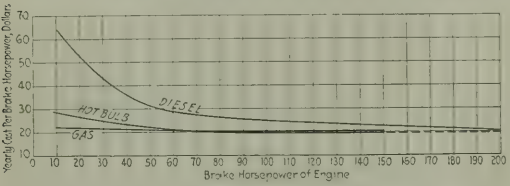


Fig. 1—Chart Showing the Comparative Operating Costs of Diesel, Hot-Bulb and Gas Engines Based upon 250-Hr. Yearly Operation

bustion engine is so far developed that no boat owner thinks of installing anything else in any boat which requires less than several hundred horsepower. In the larger sizes of boat requiring powers of say 300 hp. and over the choice is between steam and internal-combustion engines. Even in this field the steam engine is rapidly being replaced by the internal-combustion engine, so that it can be said that in the commercial motor boat field the boat owner must choose between the various types of internal-combustion engine.

There are, broadly speaking, three forms of internal-combustion engines available today in small and moderate sizes. There is (*a*) the gas engine, (*b*) the surface-ignition or hot-bulb engine, and (*c*) the Diesel engine. There are several variants of these three types, but for the purposes of this discussion only the three general types will be considered. Charts have been prepared which show certain approximate costs of operation of the three types for various sizes of engine. Before discussing these charts in detail, the basis of plotting will be given.

First Cost

These charts cover the fixed charges plus the fuel cost of operation. In establishing the fixed charges it is first necessary, of course, to estimate the cost of installation. This is variable, depending upon circumstances, but as a fair minimum the first cost has been assumed as the cost of the engine plus 15 per cent. This 15 per cent represents the cost of installing the engine in the boat complete with all piping, shafting, propellers and such auxiliaries as are necessary for the operation of the ship. In case the machinery is to be installed in an old boat, this item will be greatly increased, but the relative proportions will scarcely be changed. The first cost of the engines only has been estimated as follows:

First Cost of Various Engines

Type and Size of Engine	Cost per b.hp.
25-hp. Diesel	$200
25-hp. Hot Bulb	100
25-hp. Gas	60
50-hp. Diesel	125
50-hp. Hot Bulb	85
50-hp. Gas	60
100-hp. and larger Diesel	100
100-hp. Hot Bulb	75
100-hp. Gas	60

In considering these costs, it must be remembered that these remarks apply only to heavy-duty engines suitable for work boats. If light weight high-speed engines are concerned the proportions will be entirely changed. The total fixed charges for each year have been taken at 20 per cent in each case. This 20 per cent consists of 11 per cent for depreciation, 6 per cent for interest on the investment and 3 per cent for repairs. The depreciation item is perhaps rather severe on the Diesel engine, but for the purposes of this comparison it was thought better to assume the same percentage in all cases. For the 100-hp. sizes the fuel consumption has been taken as 6½ gal. per hr. for the Diesel, 9 gal. per hr. for the hot-bulb engine and 10 gal. per hr. for the gas engine. The fuel consumption has been increased somewhat for the smaller sizes and decreased slightly for the larger sizes It varies with the mechanical condition of the engines and the care of the operator much more in the case of the gas engine than in the hot-bulb, and the hot-bulb is more sensitive than the Diesel, but these consumptions have been taken as representing good average conditions with care upon the part of the operator. A poorer consumption on the part of the other engines will only make the case more favorable for the Diesel engine. The prices of fuel have been assumed as 10 cents per gal. for the Diesel and hot-bulb engines, and 26 cents per gal. for gasoline for the gas engine. These are less than the present day retail prices along this section of the Atlantic coast, but the price ratio will remain about the same in any case and the shape and relative positions of the curves will not be changed.

Fig. 1 is a chart representing 250 hr. of operation per annum, which is about the average for a yacht, Fig. 2

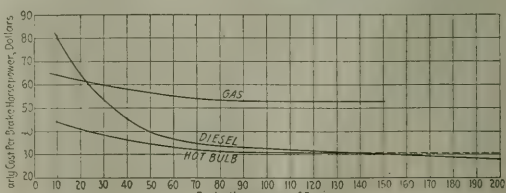


Fig. 2—Chart Showing the Operating Cost for Various Types of Internal-Combustion Engines Based on an Annual Operating Time of 1500 Hr.

[1]M.S.A.E.—Vice-president, New London Ship & Engine Co., Groton, Conn.

represen.s 1500 hr. of operation per annum, which is about the average for a work boat in a seasonal trade, and Fig. 3 is for 3000 hr. of operation per annum, which covers approximately the case of the boat which is used the year round. An inspection of these charts will show at a glance that the gas engine is out of the running entirely except in the case of the yacht; that is to say, in spite of its low first cost, the high cost of fuel brings up the cost of operation so that within the limits of sizes under discussion it is almost never economical to install a gas engine. The boat owner simply cannot afford to install a gas engine in any size where the oil engine is available.

There is another very important item in this connection which is not shown in the charts but should be brought out at this time, and that is the question of insurance. Most of these small commercial work boats are of wooden construction, and the insurance rates are high enough in any case, but with a gas engine and the presence of gasoline in large quantities with the attendant danger of fire, the insurance companies demand a higher rate of insurance than they do in the case of the oil-engined vessel. This omits, of course, the question of safety of the crew, but in a seagoing vessel this must not be ignored, and makes the case all the stronger for the oil engine. Both the hot-bulb and Diesel types of engine use a fuel of high enough flash point so that there is practically no danger of fire due to the presence of the fuel itself even with the most ordinary precautions. The hot-bulb engine has a slightly increased fire risk as compared with the Diesel engine on account of the use of open flames for heating the bulbs when preparing for a start, but this is not a serious risk even for these engines, and in some forms of hot-bulb engine, and all types of the Diesel engine, this is eliminated entirely. The question, then, comes down to a choice of a Diesel or hot-bulb engine.

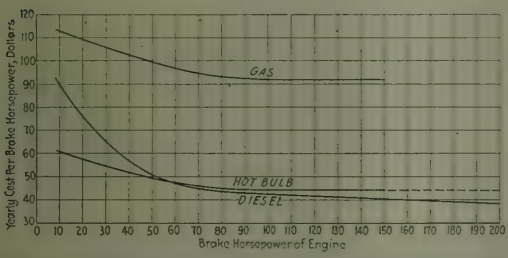


FIG. 3—OPERATING COST OF AN ENGINE IN A VESSEL WHICH IS IN SERVICE FOR 3000 HR. ANNUALLY OR PRACTICALLY THE ENTIRE YEAR

FUEL AND LUBRICANT ECONOMY

The charts show that for 250 hr. or less yearly operation the Diesel engine cannot overcome the handicap of a large initial first cost with its superior fuel economy; for 1500-hr. operation per year there is very little to choose for 100-hp. sizes and over, but as the number of hours of operation increases to 3000 the superior oil economy of the Diesel engine asserts itself and the Diesel engine has a decided advantage.

The curves do not show all of the advantages of the Diesel engine. As a matter of fact, the Diesel engine can use a wider variety of fuel than the hot-bulb engine, and more important, can use fuels of a heavier grade. With the present fuel situation, this is a factor that must not be overlooked because the present fuel outlook indicates that heavier grades of fuel will be more readily available in the future than the lighter grades, and with a Diesel engine installed the boat owner need not worry about the future in this respect; while with the hot-bulb engine there seems to be a possibility that in the future there may be such a scarcity of the lighter grades of fuel oil as to force the price upward. Another important point is the mechanical operation of the two types of engine in the various sizes. In sizes up to, roughly, 100 hp., the hot-bulb engine is reported in a great many cases to have given eminent satisfaction as regards operation, but there are several cases on record in the larger sizes where the owners have had many difficulties. On the other hand, the Diesel engine while functioning perfectly in the small sizes is very expensive to build relatively, and does not show a marked superiority in cost of operation over the hot-bulb engine. When it comes to sizes of 100 hp. and over, the superior mechanical performance of the Diesel engine and its advantage in cost of operation becomes more marked, and the larger the size of the engine the more advantage the Diesel engine has in these two respects. Along this line it is to be noted that certain makes of hot-bulb engine have added a small air compressor and changed the cycle of operation to more nearly that of a Diesel engine in the larger sizes.

FIG. 4—A YACHT EQUIPPED WITH A 120-HP. DIESEL ENGINE

The consumption of lubricating oil has not been figured into these curves, and it has been taken as the same for all of the types of engine of a given size. This is approximately true in considering the best types of hot-bulb engines working under the best of conditions, but since most engines of this type have crankcase compression and port scavenging of the working cylinder, the consumption of lubricating oil is likely to be very high unless the design of the engine provides for this contingency with special mechanical features which prevent undue leakage of oil from the bearings into the crankcase, and even with these added features they must be kept in the best mechanical condition. This means that the Diesel engine has as good a lubricating oil consumption as the hot-bulb engines under the best conditions, and under the worst conditions the Diesel engine has a decided advantage. In this connection it can be stated that a fair lubricating oil consumption for a Diesel engine is from one-fiftieth to one-seventy-fifth of the fuel oil consumption at full power.

The question of attendance is another item that has not been included, but this is more or less a constant for all sizes and types of engine under consideration. In boats of this type it is customary to carry only one engineer except in the case of large powers where the operation involves 24 hr. per day running. In the case

of fishing schooners which have 100-hp. and even in some that have 180-hp. engines installed it is customary to carry only one engineer even though non-stop runs of 80 hr. are very common. Under these circumstances the engine has to take care of itself for periods of 4 and 5 hr. at a time while the engineer sleeps. This practice is, of course, not to be recommended, but these are the actual conditions obtaining, and show the reliability and simplicity of powerplants of this type. In the case of small harbor boats, it is customary to have the engines controlled from the pilot house, and oftentimes in this case the entire crew consists of a captain and deckhand. Where 200 hp. or more is installed, and particularly in the case of vessels depending upon their engine power alone for propulsion, several engineers are carried; but in any case the number of men carried and the cost of operation depend upon the size of the powerplant and conditions of operation rather than upon the type.

No marine powerplant can be considered which is not reliable. In fact, several other shortcomings can be tolerated but unreliability cannot. The question of fire risk has already been discussed and the advantage of the oil engine shown. As for mechanical operation there is little choice as with a properly designed and installed engine, any one of the three types under discussion is thoroughly reliable as is daily attested by the large number of boats in operation which depend entirely upon these engines for their propulsion.

Mechanical Reversing Gears

It has been shown that the Diesel engine has a field almost to itself in sizes above 100 hp., and even today as young as the industry is the type of engine most suitable for this class of work has been very thoroughly proved. It will be found that the Diesel engine almost universally used in these sizes is of the four-cycle type. This is because of the greater simplicity as compared with the two-cycle type. In this size of four-cycle it is not necessary to cool the working pistons; hence all complications inside of the crankcase are omitted. Also a mechanical reversing gear is cheaper and has many operating advantages over a directly reversible engine. This means that the number of cylinders and mechanical arrangement on the engine are not primarily dependent upon the requirements for reversibility, but can be chosen to best suit other conditions. Therefore it is found that the usual type is a four or six-cylinder, four-cycle engine made reversible by the use of a mechanical gear. The four-cycle engine is also slightly more economical as regards fuel consumption than the two-cycle, and there are certain other mechanical advantages, such as reversing of pressure on the bearings and easier heat conditions in the working cylinders which make the four-cycle look so attractive.

The question of where to begin to build directly reversible engines and leave off the mechanical reversing gears is one that depends upon many factors. With a directly reversible engine a minimum of six cylinders is required to provide for reversibility under all positions of the crank; whereas if a mechanical reversing gear is fitted, a four-cylinder engine can be used which will provide larger cylinders and a lower number of revolutions per minute for a given horsepower. This is an advantage in marine work as it provides a more efficient propulsion with a reduced number of revolutions, and this is advantageous from the mechanical standpoint where hard continuous service is expected over long periods. The weight and cost is, of course, slightly increased as compared with a six-cylinder engine; but the other advantages outweigh this disadvantage. If considerable maneuvering is to be done, the mechanical reversing gear has a decided advantage, because no matter how many maneuvers are executed or how fast the signals come from the pilot house, every signal can be answered without using compressed air; and compressed air in large quantities for maneuvering engines is very expensive. Of course even on the non-reversible engine with the mechanical reversing gear the engines are started by compressed air, but the amount of air-flask capacity required is very much reduced, and very simple provisions can be made for renewing this supply; whereas in the case of a directly reversible engine the question of refilling the

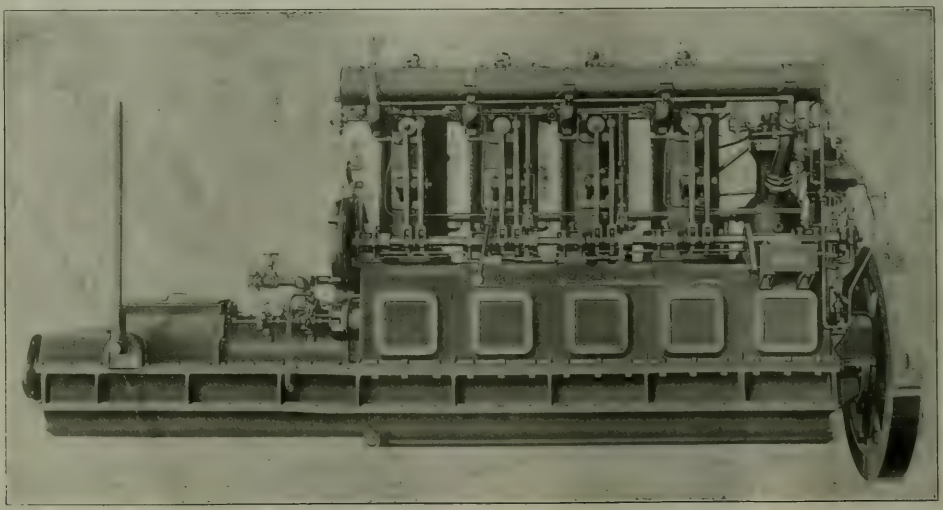


Fig 5—A Four-Cycle Four-Cylinder Diesel Marine Engine Developing 120 B. Hp. at 350 R.P.M. Which Is Equipped with a Reversing Clutch and Thrust Bearing Fitted on an Extension of the Bedplate

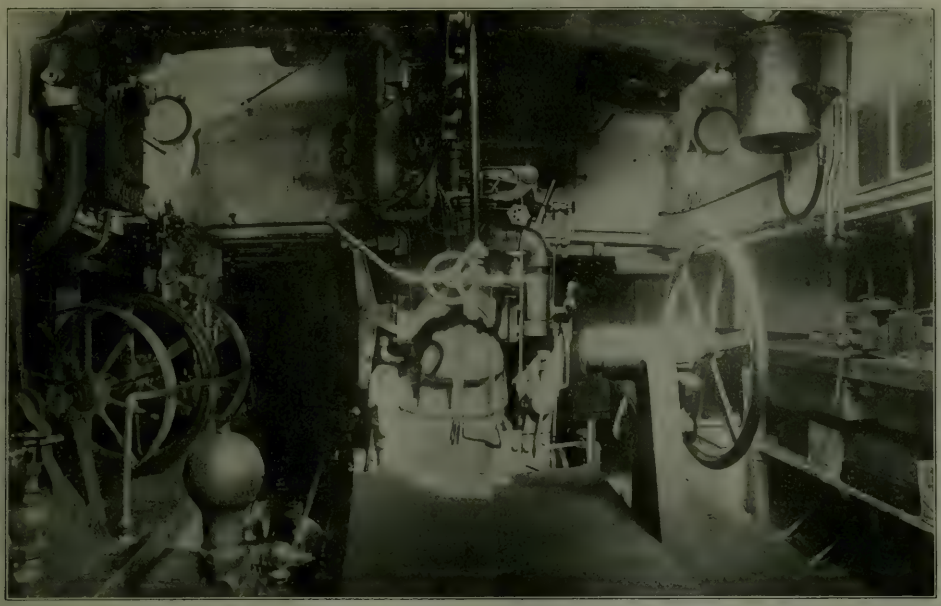


FIG. 6—THE ENGINE ROOM OF A CANNERY TENDER EQUIPPED WITH A DIESEL ENGINE

starting flasks is an important one, and in some cases would require the supplying of a separate auxiliary compressor unit for this purpose alone. When it is considered that in the case of tug boats and some fishing vessels that 5 or 6 hr. continuous maneuvering with a signal from the pilot house every few minutes or oftener is the condition to be met, the advantages of a non-reversible engine with a mechanical reversing clutch are evident. The question of obtaining a reliable mechanical reversing clutch is very important. There are many gears on the market for the smaller sizes say up to 100 hp., but in powers larger than this there are very few firms in a position to supply a clutch powerful enough to withstand the severe usage given it under the circumstances just mentioned, and in many cases the engine builder is driven to designing and building his own clutch especially for his engine. The point is soon reached in size, however, where the mechanical reversing clutch becomes extremely large, heavy and costly, and then in spite of its advantages from the operating standpoint, it is necessary to get back to a directly reversible engine. There is, of course, no definite line of demarcation, but it is considered that somewhere in the vicinity of 300 hp. it is generally cheaper to build a directly reversible engine than it is to build a mechanical reversing clutch which will be stout enough to stand up with the engine.

THE ELECTRIC DRIVE AND THE STEAM ENGINE

There is another solution to the problem of reversing the propeller in a motor boat and that is the electric drive. In this case a non-reversible engine or engines drive generators and run at a constant speed. On the propeller there is a motor which receives its power from the generators and its speed and direction of rotation are controlled by electrical means. This type of installation has several advantages, particularly for some special cases like fishing trawlers, tug boats and fire boats. In the first place it is usual to provide at least two engines even for a single-screw boat. This gives added reliability, reduces the first cost because smaller engines are used than in the case where one engine alone is used, there is extreme flexibility and the controlling of the boat from the pilot house is a very simple matter. A very important feature, however, is that in case the boat is slowed down the motor only takes the overload and the engines and generators run at regular power and speed. This particular phase is important for tug boats and fishing trawlers where for a very large portion of the time the speed of the boat is slowed down due to resistance of the tow or of the trawl, but full power is desired from the propelling machinery. In the case of direct-connected engines under these circumstances the revolutions of the propeller are, of course, decreased, which in turn decreases the power

FIG. 7—A TYPICAL EXAMPLE OF A FISHING SCHOONER DRIVEN BY A DIESEL ENGINE

output available from the engines. The advantage in the case of a fire boat is in the great flexibility of control and operation; that is the engine would drive the generators at constant speed and power could be taken as required for the motors, for propulsion and the motor-driven fire pumps.

As has already been mentioned, the Diesel engine in the larger sizes of several hundred horsepower for commercial work boats has for its principal competitor the steam engine. One particular phase of this competition is in the case of the fishing trawler. These vessels have long runs from their home ports to the fishing banks and hence require considerable amounts of fuel to take them to the fishing banks and back, to say nothing of that consumed while trawling on the banks. These boats are of course only of moderate sizes and the question of radius of action is very important. In the case of steam trawlers it actually requires an increase in the size of the boat in order to be able to carry coal enough for the round trip, and even then some of the banks in the North Atlantic which are fished from New England ports are so far away that the steam trawlers cannot carry fuel enough to make the trip. In the case of the Diesel engine matters are entirely different. The company which I represent has made two installations in boats of this character. Both of them are about 150 ft. long and carry approximately 300,000 lb. of fish. One boat has a 360-hp. directly reversible engine and the other has two 240-hp. engines with the electric drive. A speed of approximately 10 knots is obtained and these boats have a cruising radius at full speed of about 6000 nautical miles and at three-quarters speed of about 9000 nautical miles. This is more than sufficient to take them to the farthermost fishing banks and back. In other words, in this particular field the Diesel engine has no competitor and while these faraway banks are not fished very much at present on account of the plentiful supply of fish nearer home, yet it may mean in the future that all trawlers with the exception of those propelled by Diesel engines will be driven out of the business.

In conclusion then it can be said that for yachts or for any boat which operates very little, the first cost is of more importance than the cost of fuel and hence the gas engine has a decided economical advantage. This advantage is more and more pronounced as the size of the powerplant is decreased. But in the vast majority of cases, some form of oil engine is the only type which a commercial motor boat owner can consider which will meet all of his requirements. For sizes of 100 b.hp. and less, some form of hot-bulb or surface-ignition engine has the field to itself, but for sizes above 100 hp. the Diesel engine shows its superiority more and more until for 200 or 300 hp. and more, it, in turn, has the field almost entirely to itself. The ordinary tug boat, passenger boat and fishing boat uses the Diesel engine because of its economy, and the fire boat will use the Diesel engine because of its absence of standby losses. Reliability, simplicity and ease of attendance are essential in all cases, and the present day Diesel engine is fully up to the requirements.

TANK CARS

TANK cars of one kind and another have been used for about 50 years. In the beginning they were really "tub cars," a wooden vat or set of vats on a flat car. As the petroleum industry began to grow it was soon found that shipping the crude oil in barrels was too slow and costly and various designs of tank cars were invented. In general, however, the practice was to build a cylinder, strap it down on a flat car, locking it in place by blocks and braces. There was virtually no standard of any kind, no rules of construction to be observed, until 1903; if the running gear passed inspection it was presumed the car was alright. In 1903 the Master Car Builders' Association adopted rules to be followed in building tank cars, which rules continued with no important changes until 1916. In that period the growth of the use of tank cars increased enormously and it became necessary to prescribe rigid requirements to be followed in their building. As we now build it, the tank is by far the strongest, most durable, most carefully built freight car in the train. The steel plates must be of steam-boiler quality; exceptional strength is prescribed for the frame.

Originally tank cars were adopted for carrying crude oil from the wells to the refinery, the refined products being shipped in barrels. Pipe lines soon took a large part of that work from the tank cars, but by that time the use of the products of the refinery had increased so that tank cars came to be used more and more for these. Of recent years tank cars have carried chiefly loads from, rather than to, the refineries. But as the search for production goes on and new and temporary fields are brought into production, the tank car takes up again its original function and handles the crude oil from the fields not yet developed to the point where pipe lines would pay. There are many such fields now and with the constant demand for more oil and the consequent widening of the search for production this use of tank cars must increase.

It is roughly estimated that there are about 130,000 tank cars in the petroleum service in the country today, worth about $300,000,000. Hundreds of commodities formerly shipped only in carboys, drums or barrels now use long lines of tank cars. There is no such thing really as a general service tank car. For each commodity the car must be carefully adapted and designed. Loading and unloading devices, heater coils and special features of many kinds distinguish a car for one service.

The insulated tank car came into being first to meet the need for a car to handle the highly volatile casinghead gasoline. Its proved economy in operation, reducing evaporation losses to a small fraction of that occurring to shipments in plain tank cars, is causing it to be adopted for straight-run gasoline as well. Probably one of the largest single items of gasoline waste is the evaporation in transit in plain tank cars. Even in the most carefully built modern but non-insulated tank car, with a dome cover and the safety-valve fitting tight and accurately, the loss by insensible evaporation on a six-day trip in summer may run from 5 to 6 per cent or more. That means 400 to 500 gal. per car per trip.—Max Epstein at a recent meeting of the American Petroleum Institute.

THE PHOTOGRAPHIC RECORDING OF SMALL MOTIONS

THE problem of recording small and perhaps rapid motions often comes up in research work and instrument design and the pen and lever are frequently used where an optical method would be far superior. The latter is not used more probably because very little definite information is available on its design and possibilities. For this reason the National Advisory Committee for Aeronautics, Washington, has issued Technical Note No. 22 dealing with this subject. This report has been prepared by F. H. Norton, physicist in the Committee's aerodynamical laboratory, and is based upon data obtained as the result of a large number of tests made at the field station.

Petroleum Refining Processes and Problems[1]

By H. H. Hill[2]

THE problems encountered in the refining of petroleum differ greatly with different crudes and with different types of plants. The difficulties encountered in the manufacture of lubricating oils from California crude are, for example, of an entirely different nature from those encountered in the manufacture of lubricating oils from Pennsylvania crude; in the first case the chief problem is the removal of large percentages of asphaltic material, and in the second the separation of paraffin wax. The problems of each plant are more or less governed by the products that it manufactures.

Depending upon the class of products manufactured, the refineries in the country can be grouped under the four general heads of topping plants, skimming plants,[3] complete refineries and refineries with cracking plants.

In California and in Mexico certain of the heavy crudes are used directly as fuel oil, while others contain small amounts of comparatively light fractions that must be removed to obtain fuel oils with satisfactory flash-points. For the purpose of removing these lighter fractions, topping plants are generally employed. In this type of plant the oil is sometimes heated in conventional horizontal crude stills, but in most cases the stills are made up of coils of pipe through which the oil is passed continuously. The chief product of such plants is fuel oil, although the distillate or tops contain varying amounts of either gasoline, naphtha or kerosene, depending upon the crude oil used. This distillate is sometimes refined at the plant and used for blending with casinghead gasoline, but is frequently sold to other refineries. Topping plants are in many cases operated by producing or pipe-line companies for the purpose of dehydrating the oil or removing the lighter fractions prior to sending the oil to storage for long periods of time.

A type of plant that is very common throughout the Mid-Continent region is the skimming plant. Plants of this nature remove only the lighter fractions from crude petroleum, not being concerned with the manufacture of products from the heavy residues. They are generally adjacent to producing fields and, since gasoline is their most important product, are usually located in districts where crudes of high gasoline-content can be obtained. In many cases they are changed into complete refineries for by the addition of rerun stills and equipment for the removal of wax and for treating and filtering the heavier distillates, plants of this nature can be converted into refineries capable of manufacturing lubricating oils. Skimming plants produce gasoline, naphtha, kerosene, gas oil and fuel oil.

Refineries that manufacture lubricating oils in addition to the products turned out by skimming plants are generally referred to as "complete refineries." Practically all the large plants in the country and a number of the small refineries, particularly those in Pennsylvania, belong to this class. They are in most cases located at the terminals of trunk pipe-lines or operated by companies that control production and are thus assured supplies of crude for a comparatively long period. The problems encountered by plants of this type relate to the production and refining of a wide range of petroleum derivatives including lubricating oils and paraffin wax in addition to light oils handled by skimming plants.

Plants in which gasoline is produced by decomposing heavy fractions such as gas oil and fuel oil, under heat and pressure, are known as cracking plants. In a few cases plants of this nature are operated in connection with skimming plants but chiefly as adjuncts to complete refineries.

Gasoline Quantity and Quality

In the case of gasoline the chief problem at present is that of increased production. The quality, although important, is more or less controlled by supply and demand. The three methods for increasing production that appear to offer the greatest possibilities are the lowering of the volatility, increased efficiency in refinery operations and a more universal use of the cracking process. Increased yields of gasoline have been obtained to a large extent by cutting more deeply into the crude and including in the gasoline cut certain fractions that were formerly included in kerosene. This has resulted in gasolines of lower volatility, or in other words higher end-points. Only a few years ago the average end-point of engine gasoline was below 400 deg. fahr. A recent survey made by the Bureau of Mines has shown that the average end-point of products now marketed in seven large cities in different sections of the country is 456 deg. fahr. It is a question how much higher the end-point can be raised before the product will become unsatisfactory for use in the present type of automobile engine. One thing is evident, however; if the end-point of gasoline is raised much above the present figure, it will be necessary for the refiners to increase the percentage of highly volatile fractions, which at present is being accomplished by adding casinghead gasoline. The refiner who desires to increase the yield of gasoline by cutting more deeply into the crude is confronted with the problem of obtaining supplies of casinghead gasoline.

The yield of gasoline can be appreciably increased by improvements in refinery operations. As approximately 80 per cent of the gasoline produced is obtained by straight distillation of crude oil, an increased efficiency of only a few per cent would add millions of gallons to the gasoline supply. One method of increasing the efficiency of gasoline recovery is by the use of dephlegmators or fractionating towers. Most of the large refineries use fractionating towers on both crude stills and steam stills and as a result are able to obtain the maximum yield of gasoline from the crude without impairing the

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[1] From an address delivered at the convention of the Independent Oil Men's Association, Denver, Col., Sept. 30, 1920.

[2] Chemical engineer, Bureau of Mines, Washington.

[3] The terms "topping plant" and "skimming plant" are sometimes used interchangeably, the former being in accord with California and the latter with Mid-Continent usage. There is, however, a real distinction between typical plants of each class, both from the standpoint of plant equipment and in the relative importance of the products. In this paper the term "topping plant" refers to the type of plant employed primarily for the production of fuel oil, and the term "skimming plant" to operation for the production of gasoline and other light distillates, fuel oil being considered as a secondary product.

quality of the product. A large number of the small refineries do not make use of any fractionating equipment and, to obtain gasolines with satisfactory end-points, the cut for gasoline is frequently made before all fractions that could be included with gasoline have distilled off. It is believed that a general use of efficient fractionating towers would allow refiners to obtain considerably larger amounts of gasoline without increasing the consumption of crude or raising the end-point of the product.

Another means for increasing the yield of gasoline is by recovering it from the uncondensed still vapors. An appreciable amount of gasoline is not condensed when the vapors from the stills are passed through an ordinary condenser. A few refineries have installed compressors or absorbers for recovering this uncondensed gasoline and in some cases report yields as high as 2 per cent of the crude distilled or approximately 6 per cent of the total gasoline production of the plant. A large percentage of the refineries, however, have not made provisions for recovering gasoline by this method, but continue to burn this valuable gasoline fraction under their stills and boilers.

Cracking Processes

The quantity of gasoline that can be produced from a given amount of crude could be increased by a more general use of the cracking process. The Burton process, since it was first installed on a commercial scale, has produced approximately 40,000,000 bbl. of gasoline from heavy distillates and has thus saved approximately 150,000,000 bbl. of crude that would have been necessary to produce an equivalent amount of gasoline. A number of other cracking processes have been patented and a few are operating on a commercial scale, but those now in operation, including the Burton process, are using distillate oils or comparatively light residuums as crude materials. One of the most important problems in the refining of petroleum is that of producing gasoline from heavy residuums and a cracking process that could handle such oils satisfactorily would almost revolutionize the refining industry. The heavy oils of California, Mexico and the Gulf Coast, and the residual fuel oils now marketed by Mid-Continent refineries, could be made to yield enormous quantities of gasoline if a method were developed by which they could be economically utilized for gasoline production. Probably no refining problem has been the source of so much laboratory and experimental work as the production of gasoline from heavy residual oils, and although small-scale operations have been encouraging in many cases, comparatively little gasoline is now made from oils of that character.

Kerosene

For the present at least, the problem of increased production of kerosene is not of major importance. In 1919, due to the large quantities that were exported to countries that had obtained limited supplies during the war, there was a decided demand for kerosene and stocks were depleted somewhat. During 1920, stocks have been accumulating and there has been a considerable change in the export market. Although the refiners are evidently experiencing little difficulty in meeting the present demand for kerosene, the kerosenes of today are somewhat heavier products than those marketed a few years ago and are somewhat more difficult to treat for both odor and color. There is also the problem of manufacturing products of the proper viscosity to give satisfactory service in the ordinary wick burners. Due to the fact that increasing amounts of the lighter kerosene-fractions are being included in the gasoline cut, it may become necessary to either divert certain of the heavier fractions to gas oil to produce kerosenes of satisfactory viscosity, or slightly modify the present types of burners to permit the utilization of heavier products.

Lubricating Oils

The production of lubricating oils has always given the refiners more or less trouble, due largely to the fact that the various processes must be very carefully controlled to insure uniform products. There are crudes, found in very limited quantities, that are used as lubricants after having been reduced and filtered. Others, such as Pennsylvania crude, that contain very small percentages of asphalt, can be converted to lubricating oils by removing part of the wax, reducing and filtering. Other crudes, such as those obtained from the Mid-Continent, California and Gulf Coast fields, must be subjected to special treatment to produce lubricating oils free from asphaltic material.

Although the demand for lubricating oils has been increasing, there are no apparent possibilities of a shortage except in the case of special products. There is, however, a scarcity of the grade of lubricating oils known as cylinder stocks. These oils are residual products in the distillation of petroleum, are of high viscosity, have high flash and fire-points and are used for lubricating the cylinders of steam and gas engines. They are used also for blending with other stocks for the manufacture of automobile engine oils. The straight paraffin-base oils, such as are the grade known as Pennsylvania crude, are particularly suitable for the manufacture of cylinder stocks, as it is not necessary to treat the reduced crude with acid to remove asphaltic material.

Some of the Mid-Continent crudes make satisfactory cylinder stocks, but it is necessary to subject the crude to a chemical treatment before it is reduced to stock. This of course increases the cost and unless the process is very carefully controlled, the product is not always satisfactory. Although cylinder stocks are now made from some of the Mid-Continent crudes, and others tested have given encouraging results, nevertheless one of the chief problems before the refiner today is the manufacture of cylinder stocks from crudes other than those produced in the Appalachian field.

There are numerous other problems in the production of lubricating oils that are of prime importance to the refiner. Conditions for treating and filtering differ entirely with different crudes. Experimental work should be done to determine the best methods for handling each type of crude. The color of lubricating oils is a property that should be carefully studied to determine its importance as a means of judging quality. The problem of obtaining uniform products is one of utmost importance, with reference particularly to such properties as flash, viscosity and cold test.

Gas Oil

During the past year artificial-gas plants have been encountering considerable difficulty in obtaining supplies of gas oil. This product until recently was comparatively cheap and could always be obtained in adequate quantities. The increased use of artificial gas has been largely responsible for the shortage, although the high price of fuel oil has doubtless reduced the production of gas oil to a certain extent. Another possible reason for the shortage is the increasing quantities that have been used in the production of gasoline by cracking processes; the amount used for this purpose has practically doubled during the past three years.

The problem of increased production of gas oil is purely an economic one, for adequate quantities can be obtained provided the difference in price between gas oil and fuel oil is sufficient to warrant the increased cost of production. It is questionable, however, whether it would not be advisable for the gas companies to make use of the lighter residual fuel oils, in that way reducing the cost of their raw material and at the same time permitting the utilization of gas oil for other purposes such as the production of gasoline by employing some one of the various cracking processes.

Increased production of fuel oil cannot be obtained except at the expense of other products that are more valuable, namely, gasoline, gas oil and lubricating oils. It is believed, however, that the fuel oil now produced can be sacrificed to better advantage than the production of other petroleum products.

At present, the problems of considerable importance in connection with the production of fuel oil are the methods of reducing the sulphur content of oils that are exceptionally high in sulphur and means for reducing the viscosity of the heavier fuel oils.

HIGHWAY TRAFFIC REGULATIONS

THE associations represented at the organization meeting of the National Conference on Highway Traffic Regulations at Cleveland last month and invited to take part in the meeting to be held at Washington this month, were, in addition to the Society

American Automobile Association
National Automobile Chamber of Commerce
National Automobile Dealers' Association
Rubber Association of America
Trailer Manufacturers' Association of America
Motor and Accessory Manufacturers' Association
American Electric Railway Association
American Railway Association
Automobile Club of Southern California
Cleveland Automobile Club
Illuminating Engineering Society
National Association of Brotherhoods of Threshermen
National Implement and Vehicle Association
National Safety Council
National Workmen's Compensation Service Bureau
Ohio State Automobile Association
Underwriters' Laboratories
Wagon Manufacturers
American Society for Municipal Improvements
International Association of Chiefs of Police
American Association of State Highway Officials
National Automotive Equipment Association
Interstate Commerce Commission
National Highway Protective Society
Council of National Defense
Department of Agriculture
National Automotive Underwriters' Conference
National Association of Mutual Casualty Companies
International Traffic Officers' Association
National Grange
National Farm Bureaus Federation
National Team and Truck Owners' Association
Chamber of Commerce of United States
National Highway Engineers' Association
Association of Secretaries of State
Governors' Conference
National Committee on Uniform Laws
Federal Highway Council
National Thresher and Tractor Association
National Furniture Warehousemen's Association
California State Automobile Association
State Automobile Association of Indiana
State Automobile Association of Illinois
State Automobile Association of Pennsylvania
State Automobile Association of New York

The legislatures of 42 States will begin their biennial sessions this month and unless a standard vehicle law can be agreed upon, the possibility of bringing about legislative uniformity will be delayed at least two years. The necessity for the standardization of vehicle laws is becoming imperative. It is estimated that there are in the cities of the United States approximately 1,000,000 arrests for traffic law violations each year, and records indicate that a very large proportion of the fatalities and injuries caused by automobile accidents results from the violation and ignorance of traffic laws. It is expected that a traffic law adopted by the majority of the States would

(1) Reduce the number of automobile accidents
(2) Relieve municipal courts now flooded with traffic violation cases
(3) Obviate much property damage
(4) Speed up traffic in the congested districts of cities by making it possible for the motorist to know what to do and expect from other motorists

AIRPLANE STRESS ANALYSIS

A HANDBOOK of airplane stress analysis has been published, as Report No. 82, by the National Advisory Committee for Aeronautics. It was prepared in 1917, for the Chief Constructor of the Navy, Admiral D. W. Taylor, and was primarily intended to aid those who had to make estimates of airplane stresses and factors of safety for the Government.

The text, written by Dr. A. F. Zahm, comprises three parts. Part I, being introductory, presents briefly the mechanics of materials and of elementary structural members, Part II treats of airplane wing stresses and Part III treats of body stresses. Part IV, written by L. H. Crook, gives in detail the numerical solutions of the illustrative practical problems presented in the text by the use of the methods and equations therein formulated. Finally in Part V, prepared by the authors jointly, are assembled the tables, formulas and descriptive diagrams illustrating the text; also the graphical solutions of many of the standard stress problems given in the text, and previously solved numerically in Part IV.

The whole work, comprising 70 pages, is compact and orderly, with only brief arguments or explanations, and assumes that the reader has had an average engineer's training in the mechanics of materials and elementary structures. It is a handbook and not a treatise. A copy of this report can be obtained from the National Advisory Committee for Aeronautics, Washington, upon request.

A New Principle of Engine Suspension

By S. E. Slocum[1] *Illustrated with* Drawing

AMONG new developments in the automotive field, there is none which offers greater possibilities than the redesign of the engine suspension to eliminate vibration. The question of overcoming vibration is closely related to the fuel problem, for vibration is responsible for a much greater loss of power and a consequent increase in fuel consumption than ordinarily is supposed. The common impression seems to be that, while vibration is undesirable, it absorbs but a small amount of power. This is not substantiated by actual facts. Two instances are given to show what large power losses may result from vibration in certain cases. The first is that of an automobile engine which had a badly balanced crankshaft. In a road test it was found that the limiting speed for this car was about 20 m.p.h. and that it was impossible to climb a certain hill in high gear. After the crankshaft had been balanced, no other part of the engine having been touched, the limiting speed of the car was found to be doubled and the hill that previously could only be climbed in intermediate gear could now be taken easily in high.

The second instance is an experiment made by Professor Sommerfeld in 1902, and published in *Zeitschrift des Vereins Deutscher Ingenieure*, page 391, in which he clearly demonstrated the loss of power due to vibration, also determining the actual percentage of loss that may occur in extreme cases. In this experiment an electric motor was mounted on a wooden table, the idea being to reproduce the condition of a machine mounted on the upper floor of an ordinary building. When the speed of the motor was 310 r.p.m. the table began to vibrate excessively. When this vibration of the table was artificially checked, the motor instantly increased its speed, and when the table was again released, it no longer vibrated. The speed of the motor was therefore limited by the vibration of its support. When the speed of the motor was doubled, the centrifugal force, of course, was increased four-fold, and yet the table suddenly ceased to vibrate, the reason again being that the critical speed had been passed. The speed of 310 r.p.m. at which the table began to vibrate excessively was attained with a power supply of 10 watts. An increase in the power supplied merely increased this vibration without increasing the speed of the motor. In fact the speed remained practically constant at 310 r.p.m., until the power supply rose to 30 watts. In this case, therefore, two-thirds of the power supplied at this speed was absorbed in the vibration of the support. These experiments indicate not only how much power can be absorbed by vibration, but also that this power loss may be due to supporting a machine on a badly designed foundation. That is, at certain speeds, the support itself if improperly designed may absorb a considerable percentage of the indicated power.

In addition to power losses, excessive vibration has other disastrous effects. The continued reversal of stress in a vibrating body produces fatigue of the material and ultimately results in the failure of the part. This is a fact of common occurrence in all types of machinery. In the case of large machines mounted on heavy concrete foundations, such as turbo-generators, vibration results in disintegration of the concrete, allowing the machine to settle out of alignment. In electrical machinery, vibration causes poor commutation, often to such an extent as to result in serious electrical losses. These are a few instances of the waste of energy in vibration, and its destructive effects.

Critical Speeds

The most serious losses due to vibration occur, of course, at the so-called critical speed. There seems to be considerable misunderstanding as to just what is meant by critical speed. What it amounts to is that every elastic body, if displaced from its position of equilibrium and then released, will oscillate about this position with a certain definite frequency or period. This oscillation, or vibration, dies out more or less quickly, depending upon the molecular and other resistances. Such oscillations which a body performs of itself are called natural or free oscillations, and the period of such oscillations or the length of time required to make one complete oscillation is called the natural period of the body.

A body may also be forced to oscillate by the action of an impressed periodic force; that is, by an external force which recurs at equal intervals of time. For example, suppose that a shaft mounted in bearings carries an eccentric weight. When the shaft is revolved at any given speed this eccentric weight produces a centrifugal force, which produces kinetic reactions at the bearings and thereby causes the supporting system to oscillate back and forth. This forced oscillation of the supporting system, of course, has the same period as the speed of revolution. Suppose that the speed of revolution is altered until the period of this forced oscillation of the supporting system is identical with its natural or free period of oscillation. In this case we say that the two periods synchronize. The result of such synchronism is to intensify the vibration greatly and, although in any actual case the amplitude of vibration cannot exceed a certain limiting value, it frequently becomes so large as to cause failure of certain parts or even tear the machine from its supports.

By critical speed, then, we mean that speed of the rotor which synchronizes with the natural frequency of oscillation of the supporting system; that is, the critical speed is reached when the number representing the revolutions per minute of the rotor becomes identical with the number representing the number of oscillations per minute which the supporting system would perform if set in vibration and left to itself.

Every elastic body has more than one natural period of oscillation. The vibrations corresponding to these higher periods are called harmonics. A familiar illustration is that of a violin string which, in addition to its fundamental note, can be made to sound overtones or harmonics by stopping the vibration with the finger at certain definite points called nodes. Every elastic system possesses such harmonics. Consequently, there is always more than one critical speed, the higher critical

[1]M.S.A.E.—Professor of applied mechanics, University of Cincinnati, Cincinnati.

speeds corresponding to synchronism with these harmonics. It should be mentioned that these higher critical speeds are not simple multiples of the lowest critical speed, but bear a more complex relation to it, depending upon the nature of the system.

Causes and Types of Vibration

When vibration is due to centrifugal forces and centrifugal couples arising from unbalance, it can, of course, be reduced or eliminated altogether by balancing the rotating parts. But there are other causes for vibration which cannot be eliminated so easily. For instance, in an eight-cylinder V-type engine, a perfectly balanced crankshaft will not result in a perfectly balanced engine, as there are certain inertia forces arising from the reciprocating and semi-rotating parts which are not affected by balancing the purely rotating elements. Moreover, vibration due to synchronism is entirely distinct from vibration due to unbalance. The effect of unbalance is to produce kinetic reactions which are taken up by the supporting system, causing it to shake violently or vibrate. Whenever vibration is due to unbalance, it can always be traced to the kinetic reactions applied at the bearings of the rotor. Synchronism is a broader term and includes vibrations not due to unbalance or only indirectly due to it. Vibration due to synchronism may even affect machines which are not running. For instance, in one case at least it was found that the discs of a turbine rotor were vibrating, or fluttering, although the turbine was not in operation. This, of course, was due to synchronism between the natural period of the turbine disc and the operating speed of adjacent machinery. A perfect example of vibration due to synchronism is the response of a wireless receiving set to the vibrations sent out by the generating station. Clearly, such forced vibrations are due to pure synchronism and have no relation whatever to unbalance.

In the case of machinery, vibrations due to unbalance are often confused with those due to synchronism. The first esential to an intelligent understanding of this whole problem is to make perfectly clear the distinction between forced vibrations due to the kinetic reactions arising from unbalance and forced vibrations due to synchronism. For instance, it is perfectly clear to every one that an unbalanced rotor must produce some vibration of the supports, and that this vibration must be present at every speed, although, of course, it is worse at some speeds than at others. Now this supporting structure, which we will call structure No. 1, rests at certain fixed points in some kind of foundation, which we will call structure No. 2. At certain definite speeds, such as we have called the synchronous speeds, the vibration of structure No. 1 is communicated through the points of support to structure No. 2, and this effect does not depend on what causes the vibration of the first structure. We can, therefore, make the distinction that the vibration of structure No. 1 is produced by kinetic reactions due to unbalance; whereas, the vibration of structure No. 2 is due to synchronism with structure No. 1, independently of what causes the first structure to vibrate.

Elimination of Vibrations Due to Synchronism

When vibration is due to synchronism it is obvious that the cure is to destroy this synchronism. In the case of automotive apparatus, this means that a new principle of engine suspension must be introduced. For stationary machinery the same result can be accomplished by applying this new principle to the design of the understructure. The latter was discussed in a paper by N. W. Akimoff, presented at the annual meeting of the American Society of Mechanical Engineers, December, 1920.

The customary method of suspending an engine or mounting a machine consists in anchoring it down firmly to a support designed to be as rigid and massive as possible. There is no attempt to destroy synchronism, the idea being simply to reduce the amplitude of the motion as much as possible. But, in automobiles and aircraft, the entire support is elastic and comparatively light, the result being that the whole structure vibrates freely with the same period as that of the engine. Moreover, in the case of heavy machinery rigidly anchored to heavy foundations, although, of course, the amplitude of the motion is decreased, the mass that is set in vibration is greatly increased, so that we now have the case of a

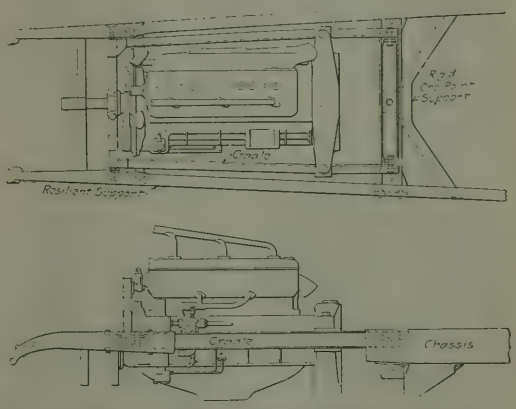


Fig. 1—Application of the Three-Point Principle of Support to Automotive Apparatus

large mass vibrating with a small amplitude. Since the energy absorbed is proportional to the mass of the body, it is evident, particularly in the case of synchronism with the support, that the power loss is not cut down exactly in the same ratio as the amplitude is reduced. It is mentioned in passing that this question of synchronism is one of the vital problems in electrical engineering at present.

It is obvious that the true solution of such problems can only consist in destroying this synchronism by isolating a machine from its support so far as the transmission of vibrations is concerned. To explain what this implies, it is pointed out first that any body may have at most six degrees of freedom; that is, it may be free to move along any three mutually perpendicular axes, giving three degrees of freedom, and it may also be free to rotate about these three axes, giving the remaining three degrees of freedom. If one point of the body is fixed, this destroys the first three degrees of freedom since the body can no longer move as a whole in any direction; but it is still free to rotate about any axis through the fixed point, so that it still possesses three degrees of freedom as regards rotation.

To apply this to the present case, suppose that one point of an engine or a machine is fixed, so that it can pivot about this point. Suppose that, in addition to this one fixed point, two other points of the machine are mounted on resilient supports. It then is evident not only that the machine will have three-point support, but

also that within certain limits it will have freedom of motion about the fixed point, due to the resiliency of the other two supports. This type of three-point support, one point being rigidly fixed and the other two supports being elastic or resilient, leaves the body three degrees of freedom, and yet makes it possible to control absolutely the period of the vibration. In other words, by properly designing or adjusting these resilient supports it is possible to change the period of vibration so as to prevent any possibility of its synchronizing with the natural period of the engine bed or foundation.

Application to Automotive Apparatus

Fig. 1 on page 55 shows one method of applying this principle to automotive apparatus. The method used in this case consists in mounting the engine in a cradle, and supporting this cradle on the chassis at three points. The rear support is here the rigid point of the three, and in this case is placed directly underneath the transmission. The two forward supports are the resilient ones and are formed by interposing coiled springs between the cradle and the chassis. A special form of double telescoping spring is used, which permits vibrations of very small amplitude, but is very rigid as regards road shocks. In fact, the action of the resilient supports is exactly the opposite of the ordinary shock absorber. The supports absorb vibration but do not respond to road shocks.

This method of suspension absolutely isolates the machine from synchronism with its support and, therefore, not only prevents vibration of the support itself but also prevents such vibration from reaching other parts or structures connected with the same support. There are also other lesser advantages of this type of suspension. For instance, in the case of tractors it is found that with four-point, and even with three-point rigid support, it is not uncommon for the engine lugs to snap off. Two resilient supports, however, give what can be called a full-floating suspension, and relieve the crankcase of any abnormal strains to which it may be subjected when all the supports are rigid. It should be mentioned again that the resilient supports are actually very stiff, although not rigid in the same sense as the frame itself, their purpose being to prevent synchronous vibration, but not to permit relative motion to any extent.

There have been several attempts to solve this same problem by using various forms of spring suspension, but none has been based on the scientific principle here used, which consists in destroying three degrees of freedom and allowing the other three to remain. For instance, one man tried three spring supports, another tried four and a third used a cradle mounted at the rear end on an axle transverse to the frame with two spring supports at the forward end, thereby allowing but one degree of freedom. Such forms of suspension cannot yield satisfactory results, as they are wrong in principle. It is apparent from what precedes that the principle underlying the design here described is radically different.

To sum up therefore, we may say that there are two main types of vibration, one due to unbalance and the other to synchronism. The first can be eliminated by well-known methods of balancing, leaving only the vibration due to torque recoil and inertia forces. The second can be eliminated by preventing synchronism, and this can be accomplished by introducing a new type of three-point suspension. The underlying principle consists in controlling the period of vibration by two resilient supports. By this means any machine can be completely isolated from its support so far as synchronism with any operating speed is concerned. This increases the life of the machine and also materially raises its efficiency, with but a very slight increase in cost, if any. It should be noted that this method of suspension supplements, but does not replace, careful balancing of all rotating parts; furthermore, that its use will improve the performance of any type of engine, although most needed by the four and eight-cylinder types.

CRUDE OIL

NEARLY all crude oils show more or less fluorescence and all show a red coloration when observed by transmitted light. With very dark or black oils it is necessary to examine thin layers to note the red color. One should remember that these colors are due to impurities, as pure hydrocarbons do not possess color. Crude petroleum may be almost as mobile as kerosene or it may be about as thick as "molasses in January." The proportion of light and heavy liquid hydrocarbons and the amount of solid hydrocarbons dissolved will govern the fluidity of the crude oil. Some crude oils have an odor much like that of gasoline or kerosene. Such a crude oil will obviously contain a large proportion of the lighter volatile hydrocarbons. Petroleum which is lean in light stuff may have almost no odor save that inadequately described as "oily." The heavier hydrocarbons when pure are practically odorless. If sulphur compounds are present, a crude oil will have a rather nauseating odor. It is difficult to describe these sulphurous odors, though they are sharp, very disagreeable and decidedly characteristic. Sometimes hydrogen sulphide gas is dissolved in the oil and its characteristic, rotten egg odor is very much in evidence. Crude oil may vary in specific gravity within rather wide limits, the proportion of light and heavy constituents governing this property. Some crude oils are very light with a gravity as high as 49.5 deg. Baumé, equivalent to 0.780. Others may be much heavier, with a gravity as low as 11.4 deg. Baumé, equivalent to 0.990, which is almost as heavy as water. Some few petroleums contain so much light stuff that they will burn in the ordinary internal-combustion engine. Naturally the continued use of such a fuel would be somewhat hard on an engine because of the impurities and the impossibility of obtaining complete combustion of the heavier hydrocarbons with a carbureter and an engine designed to handle only light stuff.

Most of the oil wells of the United States today are being pumped. As the oil comes from the earth it may or may not be mixed with considerable water, suspended mineral matter and "bottom settlings." The latter consists of inert organic matter mixed with finely divided mineral material. Some oils are mixed with a great quantity of water, either fresh or salt, and practically all carry a small amount.—C. J. Frankforter in *Oil News*.

A MILESTONE OF AUTOMOTIVE PROGRESS

THE Studebaker Corporation, South Bend, Ind., has discontinued the building of wagons. It will continue to produce and supply repairs for the many Studebaker wagons in use. Thus will pass from the market one of the oldest and best-known farm wagons. The discontinuance of this line reflects the progress of the motor vehicle.—*Farm Implement News*.

TRADE BALANCE

AMERICA'S trade balance cannot be definitely calculated from the excess of our exports over imports. If our enormous foreign loans are taken into consideration, the actual exports of this country could drop very much lower than they have without impairing our real trade balance.—O. P. Hopkins, Bureau of Foreign and Domestic Commerce.

Inspection and Testing in Interchangeable Manufacture

By Earle Buckingham[1]

With any system of inspection the tendency of the productive departments is to neglect all thoughts of the ultimate use of the parts in process and to concentrate on efforts to increase production, the standard of quality apparently being anything that the inspector will not reject. Thus, an unfortunate situation almost inevitably arises, the production departments considering only the detailed manufacturing problems and constantly seeking the line of least resistance as regards the machining, while the inspectors either connive at this or arbitrarily insist on the exact letter of the drawings and specifications without regard to the ultimate use of the part in question.

Neither of the above forms on inspection is satisfactory. Seldom, if ever, are the drawings and specifications complete or correct enough to be followed blindly. The mere meeting of the drawing requirements is not in itself the prime object of manufacturing. The main purpose in all branches of interchangeable manufacturing is to promote the economical production of satisfactory mechanisms. If the inspection is to accomplish its part in this work discretion should be used, and due consideration should be given to many factors.

Discrepancy Between Part and Drawing

When a piece of work is not in accordance with the component drawing, any one of several conditions may be present; (*a*) the part may be wrong and the drawing correct; (*b*) the part may be correct and the drawing in error; (*c*) both the part and the drawing may be correct, and (*d*) both the part and the drawing may be wrong. In the first case, if the part cannot be salvaged, it must be scrapped. In the second case, the part should be accepted and steps taken immediately to have the drawing corrected. The third case requires more consideration. For almost every problem there is more than one satisfactory solution. If the part as completed can be reproduced at a lower cost than one made in accordance with the drawing, the part should be accepted and the drawing corrected accordingly. But if the part as made is more difficult to reproduce, the drawing should remain unchanged, although the part need not be rejected. In the fourth case, if the part cannot be salvaged, it is, of course, scrapped, but the necessary corrections should be made on the drawing as soon as possible.

In all of this work, due consideration must be given to the succeeding manufacturing operations and equipment provided for performing them. When elaborate manufacturing equipment is provided, it is often cheaper to scrap parts that might otherwise be salvaged, because of the difficulty of completing them with the existing equipment. It is obvious that when a great volume of production is involved discretion can be exercised by but a few of the inspection personnel. Hence any abnormal volume of rejections by the inspectors should be the occasion for a reinspection of the rejected parts by persons competent to locate the error, whether in the parts or the drawings. The original drawings seldom give information complete in every detail which is necessary to produce every part. The production departments, however, must complete the parts with or without the assistance of the drawings and specifications, while the inspection department must decide whether or not the parts thus produced are satisfactory. The first solution of some of these indefinite points may not be the best one, and several different methods may be tried out before one that is entirely satisfactory is reached. During all this development, the inspector must give earnest consideration to the problem, so as not to delay production unnecessarily and still insure a satisfactory product. As soon as any problem is solved, the inspection department should be responsible for passing the information along to the proper persons so that it may be recorded.

This makes it clear that the inspection department, among its other duties, must act as eyes for the engineering department. For this reason, in some plants the inspection department reports to, and is virtually a part of, the engineering department. In other plants, it is a distinct department and is responsible to the managament. Either plan usually works out well. In no event should it be a part of, or subordinate to, any production department. The duties of the production and the inspection departments are so incompatible that they should never be combined, and if they are, one or the other is bound to suffer. Nevertheless, the inspection should be carried on in close cooperation with the production departments, as well as with all other departments of the organization.

The mechanical inspection of component parts falls logically into two main divisions. The first is the shop inspection which is performed while the parts are in the process of manufacture. The object of this inspection is to cull out defective work as early as possible and to discover any defects in the manufacturing equipment which result in faulty work. The second division is the final examination of the completed parts. The object of this is to see that all components that will function properly are accepted, and all unserviceable parts rejected. There is also the inspection, or testing, of the assembled mechanism to detect faults that have not been detected prior to assembling the parts.

Shop Inspection Methods and Personnel

When the production is continuous, the shop inspection should be established so that the parts are rigidly inspected after each machining operation on every important functional surface. The requirements of these surfaces should be definitely determined and recorded as early as possible, and these requirements should be rigidly maintained. These inspections are as important as any of the productive operations, and should be maintained accordingly. The inspection of non-functional and other unimportant surfaces can usually be handled by an inspector who passes from department to department and periodically checks a small percentage of the product at each machine. If any errors are discovered, the machine should be stopped and the set-up corrected, but the parts at fault should not necessarily be rejected. The inspectors are, of course, supplied with the necessary gages, limit gages being essential for most of the important functional surfaces, while "go" gages alone are usually sufficient for surfaces of lesser importance. Definite lists of the essential inspections or important functional surfaces should form a part of the specifications. These may be combined with the operation lists or may be made up as separate schedules. Whether or not each individual piece of work should be inspected depends largely on the character of the operation. On many automatic operations, a percentage inspection is sufficient, while on most hand operations, where each piece is handled individually and the personal skill of the operator is a factor, a 100 per cent inspection is usually required.

The inspection of screw-machine parts made from bar stock is the case where the inspection of a minor percentage is sufficient. The practice in one plant is as follows: Each automatic screw machine has, as part of its equipment, several small metal work boxes or baskets which are numbered consecutively. These are used in order, and about every 15 min. the one on the machine is removed and placed

[1]M. S. A. E.—Engineer, Pratt & Whitney Co., Hartford, Conn.

on a bench, while the one with the next number is placed on the machine. An inspector makes periodical visits and inspects a few parts from each basket. If these are satisfactory all the parts are removed and the empty basket is returned to the machine operator. If a faulty piece is found in any basket, the entire contents of that basket, all succeeding ones, and also the one preceding it, are set aside for a 100 per cent inspection while the machine is stopped immediately and its set-up corrected.

This general plan is adaptable to many other operations, such as sub-press die work and other punch press operations, for example, where the set-up and conditions of the tools alone practically control the uniformity of the product. The shop inspection should be carried on as soon after the machining operations as possible. In the case of very large parts the piece is often inspected before it is taken from the machine, which saves a new set-up if corrections are necessary.

Much of the detail work of testing the parts with gages, particularly on small work, requires little mechanical knowledge or skill, and is often satisfactorily performed by girls. When the quantity of production is large, and the inspections are subdivided into elementary tasks, a relatively small amount of training will develop efficient detail inspectors. The supervisor of such work, however, should be not only a good mechanic, but also a person well acquainted with the requirements of the product. The successful chief inspector must be firm but diplomatic; his duties must never degenerate into fault finding.

The person in charge of the shop inspection has one of the most difficult positions to fill. A great part of his work in promoting economical production is to prevent faulty parts from being made. When an operation is first set-up, the product should be checked. If it is satisfactory, the succeeding parts must be watched, so that the set-up may be corrected before any work is spoiled. If the first parts do not meet the requirements, the set-up must be corrected before production in quantity is started. To fulfill these duties properly, without antagonizing those engaged in production, is a delicate task and the closest cooperation is necessary. An arbitrary inspector will soon stop production entirely. On the other hand, an inefficient inspector can soon ruin the repuation of the firm. A grave mistake on the inspector's part in either direction will inevitably cause much needless expense.

Final Inspection of Work

In many ways the function of the final inspection is very different from that of the shop inspection. The latter deals with the parts as they are being shaped from the raw material. Nothing should be left undone to promote their completion in accordance with the drawings and specifications. The final inspection, on the other hand, deals with the parts after all the machining operations have been completed. Its main function is to see that all parts which will give satisfactory service are accepted, and that those which will not are scrapped. This result alone should be striven for, regardless of technical violations of the drawings and specifications. Under normal conditions, such violations should be rare. If conditions are abnormal, steps should be taken to correct them, but such steps should never involve the rejection of serviceable parts.

In general gages used in the final inspection should be functional gages only. If the detailed shop inspection is properly organized, there is no need to duplicate it here. If it is not functioning properly, the trouble should be corrected at its source. Both the shop inspection and the final inspection should be under the general direction of the same person. All final decisions as to the acceptance of questionable material, whether questioned by the shop inspection or the final inspection, should also be made by the same person.

One of the duties of the inspectors who perform the final inspection should be to watch the work of assembly in addition to testing the assembled product. If the component parts assemble properly and the completed mechanisms function as they should, no further evidence is needed that the productive work has been properly done. If the parts give trouble in assembling or the mechanism fails to function, immediate steps should be taken to locate the trouble and correct it at its source. Thus the assembling departments form the best points of advantage to watch and judge the results that are being obtained.

The inspection of the gages used in the course of manufacture is one of the vital functions of the inspection department. As gages become worn, they permit parts larger or smaller, as the case may be, to pass inspection. The adjustment of a machine or tool is not changed as long as the parts produced satisfy the gages used in their inspection, and so all gages should be checked periodically and corrected or replaced as found necessary. Too often this is not done until trouble has developed. One of the principal objects of inspection is not to locate the cause of trouble after it has happened, but to forestall and prevent it. A systematic inspection of gages is one of the surest means of accomplishing this end.

Most of the inspection of the composition and physical strength of materials belongs in the chemical and metallurgical laboratories. When a part is subjected to unusual stress, it is customary to make a chemical analysis of each bar of stock as it is received. This and other specified physical tests are seldom considered in connection with the mechanical inspection of the product. Often, however, after such operations as forging, hardness tests are made in conjunction with the other inspections to insure that the metal is in proper condition to be readily machined. Such tests are usually made with simple testing instruments, such as the Brinell testing machine or a scleroscope, the mechanical operation of which require no more skill than the proper handling of gages, and are, therefore, usually conducted by the regular mechanical inspection personnel.

Whenever possible, the assembled mechanism is tested by actually having it perform the work it is intended for. Thus, a newly completed automobile is usually sent out for a road test before being shipped; a typewriter is manipulated by an operator; a rifle is tried out by a marksman, etc. These tests, of course, only prove the condition of the mechanism while new. The test of service depends upon the materials used in its construction and the honest workmanship which has been built into it at every stage beginning with the designing and followed by the careful and watchful work of the productive operators, the vigilance and good judgment of the inspectors and the care and attention of the assemblers, No one factor is predominant. All are essential and each one must be carefully studied to develop and maintain a smooth flow of production.—*Machinery.*

RADIO TELEPHONE

THE growing usefulness of the radio telephone in its application to aviation exemplifies itself every day. By enabling the flier to keep in constant communication with the earth, it gives him speech and hearing and, by so doing, keeps him apprised of weather and other conditions ahead. The psychological effect upon the flier of this invisible link with the earth, this intangible evidence of "human touch" is incalculable. To a very decided degree it reduces the sense of hazard as it actually minimizes the danger by affording him indubitable evidence of the physical conditions to be encountered throughout his route.

In recognition of its importance to aviation, the Belgian, French and British governments have established a line of the phone stations along the Paris-London and Brussels-London air routes. Stations now operating are located at Croydan just outside of London, at Lympne on the English side of the Channel, at a point off the French coast and at Paris. Preparations are also in progress to establish other stations at convenient intervals in England and France.—Air Service Letter.

Some Inland Waterway Transportation Problems

By V. E. Lacy[1]

Semi-Annual Meeting Paper *Illustrated with* Photographs

THE problems of inland waterway transportation are more a matter of public education than anything else. Given the waterway on which suitable boats can be navigated, the problems of the vessels themselves and their methods of propulsion are by no means difficult. To arouse proper public interest in water transportation is the one big problem. The American public has become so thoroughly educated to the railroad as a means of inland transportation that it is very difficult to bring it to the point of thinking about waterways boat transportation. Even at this time of serious transportation congestion, caused by the inability of the railroads to handle the freight offered, it appears that comparatively little is being done in the way of developing waterway transportation. It is increasing but in nothing like the proportion that is possible.

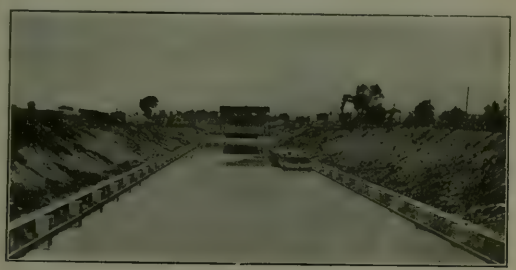
Combination Mohawk (at the Right) and Sector Gate (at the Left) Dam at Rochester, N. Y., Forming the Harbor by Raising the Genesee River to the Canal Level

It is reported that for the first month of 1920 navigation on the New York State Barge Canal the tonnage passing Troy was 94 per cent greater than for the same month of 1919. It is reported also that all of the available boats are in service on this waterway and that much more tonnage is being offered than these boats can accommodate. That so much freight is being offered for water shipment over this route is most encouraging. The discouraging element is that little has been done to provide the necessary boats, and little is heard in the way of reports of projects for the future. The total of boats operated on this canal in 1920 will probably not exceed 500. The capacity of the canal would not be reached by operating 10 times this number. In the palmy days of the old Erie Canal there were 6000 boats in operation and the new canal has many times the capacity of the old one. Of course, a few new boats are under construction and several corporations along the canal are making preparations for fleets to transport their raw materials and finished products to and from their works.

Guard Gates at Each Side of the Genesee River Crossing, Their Use Being Made Necessary by the Fluctuations in the Level of the River

The problem of motive power for canal barges is a large one. The ideal propulsion has not been developed yet. But the means at present available are sufficiently satisfactory to avoid delay by waiting for the development of the ideal motive power. In my opinion the internal-combustion engine in some form will be found eventually to be the most desirable power. At present, however, little thought is being given to any power other than steam. The great advantages of steam power are its flexibility and the development of great power at very low rotative speeds. The latter is highly desirable because the greatest propulsion efficiency for towing and driving heavy barges at low speed is attained by means of a slow-turning, large-diameter and comparatively low-pitch propeller. It seems that extreme flexibility and low speed are the only really important advantages of steam over the internal-combustion engine.

Viewing the problem from the standpoint of the



A Land Cut with Concrete Walls West of the Genesee River Crossing with the Guard Gates Showing in the Distance

[1]M. S. A. E.—President, Rochester Boat Works, Inc., Rochester, N. Y.

internal-combustion engine, the question arises as to what form of this type of engine would be most suitable. In respect to flexibility the gasoline engine is by far the best, but it cannot be considered for this purpose on account of the high cost of its fuel. Other difficulties with large gasoline engines will readily come to mind. Two types of internal-combustion engines offer great possibilities for canal-barge propulsion. These are the heavy-oil engine and the gas engine taking its fuel from a producer. It is certainly possible to develop either of these types into a wholly satisfactory powerplant for this purpose. The chief difficulties are to secure the desired flexibility and to keep the speed down to the point where proper propeller efficiency can be maintained. It seems that both of these conditions can be attained reasonably closely; the extreme flexibility of the steam engine is not necessary and a slight loss in propeller efficiency can be more than made up by the greater thermal efficiency of the internal-combustion engine.

Canal-Barge Engine Requirements

To meet the required conditions the engine must be a heavy slow-turning one capable of a wide range of speed. The full-power speed should not exceed 250 r.p.m.; 200 would be more desirable. A steam engine would operate at probably 120 to 150 r.p.m. or less. If the engine operated at 200 to 250 r.p.m. at full load, it should be capable of throttling to 75 r.p.m. This would, of course, necessitate a very heavy flywheel, unless a multiplicity of cylinders were employed. In this connection, the number of cylinders should be as few as possible, but in my opinion there must be three, and the next and only other step is to employ six. The three and six-cylinder engines possess the necessary features to provide suitable reversing means, whereas a four-cylinder engine does not possess them except when it is of the two-cycle type, when the cranks can be set at 90 instead of at 180 deg.

One object in using a small number of cylinders is to reduce the length of the engine. Another is increased simplicity, which is very desirable because the class of men who will operate the engines are not capable of taking proper care of an intricate piece of machinery. More cylinders necessitate more bearings and a greater number of other working parts, requiring a higher type of man to keep everything in proper order. A multiple-cylinder gas engine in its simplest form is more or less of a puzzle to the steam engineer who has spent his life alongside a single non-condensing or compound-condensing steam outfit. All things considered, a good gas engine is easier to keep in condition than a steam outfit of similar power and relative excellence, but the old-time steam engineer does not think so and it is very hard for him to learn this. It is not that the engineers themselves will be recruited largely from the ranks of those devoted to steam, but those higher up, who determine what will be used as a propelling power, are almost invariably steam-engine sympathizers. Something must be shown them that will appeal as being a suitable substitute for the steam engine.

Concerning the question of oil versus producer gas there seems to be no reason why perfectly satisfactory plants cannot be developed in either type. Each has advantages over the other but, all things considered, their general desirability is probably about equal. The producer is more-or-less bulky, although of course not nearly so large as the steam plant boiler. It also requires very careful firing and attendance to make it deliver a satisfactory gas; it is by no means a device to be put into the hands of a novice. From the standpoint of economy it is likely that a producer plant would deliver power at a lower cost per horsepower than any other. The oil engine would be a close second. With regard to first cost the producer plant would, I think, have a slight advantage over a first-class oil engine of the Diesel type. In the matter of weight there would not be much difference. The massive proportions of the Diesel engine would probably be more than duplicated by the producer. In either case the weight would be less than that of an equal steam plant with its boiler full of water and, of course, the space occupied by either would be much less, thus giving greater cargo capacity. In point of space occupied, the oil engine has the advantage. Power for power there would be but little difference in the actual size of the engines, whereas the gas plant must have space for its producer.

Reversibility

Reversibility is a matter of great importance when considering any form of internal-combustion engine. It is the one bugaboo of all types of marine gas-engine. In small marine plants this is taken care of in a fairly satisfactory manner by means of gears of various designs, but for engines large enough to propel canal barges and tow two or three others the gear method seems to be out of the question. The alternative is the reversible engine.

Reversing is most often accomplished in existing designs by some method of shifting cams; that is, two sets of cams are arranged along the same camshaft or shafts. One set is for forward drive and the other for the reverse. To engage either of these sets of cams, the camshaft is usually arranged to slide. This is done in smaller plants by a hand-lever or wheel and in larger engines by air-pressure. Starting in either direction is generally accomplished by air pressure admitted to the cylinders. Usually this is by means of a set of cams in a distributing device. This consists of a common chamber connected to the air-pressure tank and a series of poppet valves admitting air in suitable sequence into a series of pipes leading to poppet valves in each cylinder. The cams must be arranged to shift suitably simultaneously with the main cams for reversing the motion. Whatever system is used for reversing, it is requisite that it be absolutely positive. There must be no chance of the engineer failing to answer the signals from the pilot-house. It will, of course, be granted that no device or system can reverse a gas engine as quickly as a steam engine can be reversed, but, with a positive means of reversing with reasonable promptitude, no trouble need be experienced, as the man at the navigating end of the ship can easily learn to figure on what to expect from the engine-room. In working a boat through a canal with its multitude of locks, there must be no doubt about the navigator getting the results he signals for. Failure to reverse is likely to be very serious and far-reaching. Since starting the engine in either direction is usually accomplished by air pressure, both direct-connected and auxiliary means of providing compressed air and tanks for storing it must be provided. This system of compressors and tanks should be of about three times the capacity which might be expected to serve under normal circumstances. The designer must consider the conditions of crowded harbors and see to it that air-pressure will be always adequate when signals come down to the engine-room thick and fast.

A very simple means of reversing is possible with the

producer-gas engine. It is a method that ought to work out very satisfactorily. It consists of an arrangement of the exhaust and intake manifolds in which, by means of suitable valves, their purposes are reversed for reverse motion of the engine. In this case the manifolds are made alike in every respect. The valve arrangement would serve to cut either manifold into gas and the other into exhaust, depending upon the direction of rotation required. Linked up with this valve-operating system means would be provided for shifting the air distributor suitably. The main exhaust and intake cams can be alike, or, for better efficiency in forward drive, they can be designed with special reference thereto, and the reverse can be allowed to take care of itself, provided, however, that there is not so much difference in the cams so as to make them impracticable when used for opposite purposes. It is not likely that this would be the case. This reversing system has been worked out in a manner which seems perfectly feasible.

Power Required

The amount of power necessary for a canal barge depends, of course, upon the size of the barge and the number of tow barges it is intended to haul. The New York State Barge Canal was designed for barges of 1000-ton carrying capacity. The locks and all other elements of the canal are large enough to accommodate much larger vessels, but the consensus of opinion among experienced canal men is that vessels of about 700-ton capacity are the most desirable. These barges would be operated in fleets of four, a power barge and three consorts. When operated in this way, if the whole fleet is to lock through at one time, the boats would be about 140 ft. long, 21 ft. beam and 12 to 13 ft. depth of side. The boats, loaded, would draw from 9½ to 10 ft. of water, and the fleet would just nicely work through the locks, which have a length of 310 ft., width of 45 ft. and depth of water over their sills of 12 ft.

About 500 hp. would be required for a power barge of the size mentioned to be operated in the manner stated. This amount of power would probably propel the fleet 5 m.p.h. If greater speed should be required, more power would be necessary of course. But great haste is not usually essential in the transportation of such freight as these barges will handle. Economy is the important consideration and an additional mile or two per hour would add very greatly to the cost of propulsion when considered from the standpoint of the cost of power only. The desideratum is to arrive at a proper balance

One Steamer and Four Government Steel Barges Just Filling a Lock Which Has a Lift of About 16 Ft., the Time of Locking Through Approximating 30 Min.

A Lock Powerhouse Where Waterpower Is Used to Generate Electricity for Operating the Lock Gates

of the elements of fuel cost and operating cost. Too slow a pace would run into great expense in wages of crews; and if too much speed is attempted, the fuel bill will run up. The limit of speed on a large part of the canal is 6 m.p.h. and in some places 4 m.p.h. In the canalized river stretches a speed of from 8 to 10 m.p.h. is allowed. It is not likely, however, that a speed of over 6 m.p.h. will be found economical in the long run.

At this time anything in the way of a good barge from 250 tons up can, if properly fitted out and suitably propelled, be operated at a good profit. Shippers, barge builders, engine builders and their associated industries should work out the problem of water transportation. If the matter is energetically attacked by all interested, it will be but a short time before very material relief from the present congested traffic conditions will be felt. Anyone who will carefully study the map of the eastern half of the United States will be literally astounded at the possibilities of inland water-transportation development. We have several very fine routes ready for use, but have only scratched the surface of the ultimate possibilities.

THE DISCUSSION

G. R. Pennington:—Why is it that so few boats are operating on the canal?

Mr. Lacy:—The old canal became too small for commercial use in that the old canal boats were not especially economical as compared with other modes of transportation. The State decided to build the new canal and during the process the navigation on the canal was destroyed. Since that time the public has withdrawn its attention from inland water navigation. The unfortunate feature is that no adequate preparations have been made for the building of new boats. Very little boat building is going on. There is considerable activity in the way of making plans at present, and it is hoped that many new boats will be brought out. All available boats are running now.

Mr. Pennington:—How are the boats propelled?

Mr. Lacy:—They have mechanical propulsion of some kind; it is mostly by steam and largely by tug boats. I predict that the internal-combustion engine will be the future powerplant for driving canal boats.

A. K. Brumbaugh:—How are the barges in tow arranged? Has any difficulty been found at the curves of the canal?

Mr. Lacy:—There has been no difficulty. It has been proposed that very large barges be built that would practically fill the locks; barges approximately 275 to 300 ft. long and 40 to 42 ft. beam. Old canal men say that such barges would be very impractical, owing to their unwieldiness and inability to make the turns. The shorter boats can make the turns because one boat is put

behind another and a means of steering is provided by bending the fleet, one boat acting as a rudder.

MR. BRUMBAUGH:—Hs any difficulty been experienced with the dam construction?

MR. LACY:—It has been very successful, having passed through several winters. Some of the dams or the Mohawk River have been in operation for seven or eight years. Everything has worked out satisfactorily. The New York State Barge Canal is a wonderful piece of work. It is a fine structure from beginning to end.

WALTER C. KEYS:—What did the barge canal cost?

MR. LACY:—It has cost approximately $200,000,000 to date.

MR. PENNINGTON:—Who operate on the barge canal; individuals or corporations?

MR. LACY:—Either. There is no limit to the size of corporation that can operate on the canal at present. Formerly corporations were limited to $50,000 capital.

MR. PENNINGTON:—Does the traffic pay any part of the fixed charges resulting from the cost of building the system?

MR. LACY:—There are no tolls.

MR. PENNINGTON:—Why is it that the traffic does not build up rapidly?

MR. LACY:—The canal has been operating only two years; the large barges could not navigate the full length of the canal before 1918.

MR. PENNINGTON:—Is the War Department still in control of the canal?

MR. LACY:—Yes.

PLOWS

ONE who reads history and then looks out over our factories and fields to-day can scarcely realize that our industrial era is barely more than a century old. No one who goes through the country and notes the great array of farming implements for every farm operation can realize that as short a time as 85 years ago there was not a single really good plow in all the world.

The old-style plows of Europe and Asia merely broke and stirred the soil; they did not turn a clean-cut furrow. Mostly they were made of wood with a bronze or iron point. The moldboard was either lacking or was a crude affair of wood that did nothing more than push the soil aside. In medieval times the French had a clumsy two-wheeled plow which was used without change for centuries. This plow was improved somewhat by the Dutch in the seventeenth and eighteenth centuries, but the first notable advance in the art of plow-making was made in England when Foljambe took out the first patents which improved the Dutch plows. He is said to have been the first to use a plow clevis.

Later on a Scotchman, in 1763, established a plow factory and began to make iron plows. The body and handles were of cast iron and the share was made of wrought iron. These were the justly famous East Kothian plows. Another improvement was made in these plows in 1803, when Robert Ransome developed a process of casehardening the moldboards.

Charles Newbold is said to have taken out the first American plow patent in 1797. He produced a cast-iron plow and spent upward of $30,000 trying to get it established, but failed because of the prejudice of the farmers. The next American to undertake the manufacture of plows was Jethro Wood, in 1819. His chief contribution to the art was the principle of the interchangeability of parts. This ushered in a new era not only in plow-making, but in manufacturing generally. His plow was rather crude and consisted of a soft gray iron moldboard supported upon a wood framework.

Up to 1840 most of the land under cultivation in America was largely new land or land that was full of sand and gravel. It was easy to cultivate because it was full of humus and vegetable mold, as is all new land. The farmers managed to get along somehow with the old crude plows when the soil was young, but as it grew older troubles developed. The plows did not scour so well where clay predominated, while in sandy and gravelly soils they wore out rapidly. These plows were heavy and crude. They did not turn the furrow very cleanly, they were difficult to keep in the ground and they required much more power than modern plows. Still, despite these obvious handicaps, the farmers of those days managed to get along very well until the tide of immigration carried the first settlers westward to the prairies of Illinois. Here they found a soil that refused to scour with any of the plows which they carried with them from the East. The sod was tough, and below this sod was gritless soil as fine as flour and as sticky as dough. An empire awaited development, an empire of the richest land in the world, but it was practically valueless with the tools the farmers had to work with.

Many experiments were undertaken, but it remained for a humble blacksmith of what is now Chicago, John Lane by name, to find the solution. He conceived the idea of a steel moldboard in 1833. The solution of the soil problem had been found. It was not until about 1840 that the rolling mills recognized the infant industry sufficiently to roll special plates 12 in. wide, for plow moldboards.

In those early days all the blacksmiths in Illinois and the Middle West were plow-makers. They carved out the wooden moldboards according to their individual ideas of proper form and then faced them with boiler plate or steel. In 1837 a young Vermonter with initiative and mastery of the art of blacksmithing settled at Grand Detour, Ill., and started making steel plows. This was the real beginning of the steel-plow industry, an industry that ranks in national importance with harvesting machinery and our transportation systems in the development of the nation's resources. Without the steel plow the Mississippi Valley could not have been put so quickly under cultivation and the Prairie States would not yet be developed.

Deere, at Moline, and Parlin, at Canton, were responsible for the development of the steel plow in America. In 1868 John Lane, Jr., the son of the man who first used a steel moldboard, invented soft-center steel, an epoch-making discovery that lifted the steel plow industry to new heights of efficiency. In 1855 James Oliver bought a small foundry at South Bend, Ind., that had been making cast-iron plows for a number of years. They were clumsy, heavy and the moldboards were too soft. He had visions of a moldboard without fault or flaw, glass-hard and polished like a silver mirror. He succeeded in developing such an implement. He knew that the secret of success lay in discovering how to make a chilled casting that would be hard yet not brittle, and one that would be free from blowholes. He laid the foundation for an immense industry.

The development of the plow, especially the multiple-bottom plow operated by horses or tractors, has been revolutionary in its effects not only upon agriculture but upon all other forms of industry. It has released millions of men from the task of preparing soil for the crops and has thereby been a powerful factor in building up American manufacturing industries to their present position of prominence.

The reign of the crooked stick has been a long one. It still holds sway among hundreds of millions of peoples. We discarded it more than half a century ago and since then our progress has been rapid. When all the world does likewise we shall witness a new order of things with undreamed-of possibilities for good or evil, for the plow is a revolutionary implement.—P. S. Rose in *The Country Gentleman.*

PETROLEUM FROM SHALE

THE principal commercial oil shale is generally known as torbanite. This name is derived from the Torbane Hill mine, Scotland, where the shale was first mined and retorted successfully. It is a brownish or dark black, fine-grained, schistose shale having a fawn-colored streak without luster and a subconchoidal fracture and gives off curled flakes like shavings when scratched with a knife. Sometimes it resembles coal and occurs in bedded deposits in similar formations. On many of the oil-shale fields, like those of Nova Scotia, Newfoundland, Scotland, New South Wales, Colorado and Utah, coal seams exist above the shale beds. Oil shales occur also in irregular blocks interspersed in sedimentary deposits, but such deposits are of little commercial importance.

The usual solvents for paraffin and resin do not dissolve anything from oil shales. This indicates that petroleum bitumen and paraffin are not contained in the shales in a free state. The organic matter on being attacked by the metallic oxides has been converted into an insoluble carbonaceous compound known as kerogen.

There appears to be a graduation in oil content from peat up to the highest grades of torbanite. The paraffin and oil contents of peat are small, of bituminous coal moderate, and of torbanite high. Some of the torbanite from New South Wales carries as much as 125 gal. of oil per ton. It is also found that the crude oil content diminishes and the ammonia increases proportionately with the age of the shales.

Shale Mining and Distillation

The shale beds are mined exactly like coal deposits. Some of the large commercially valuable deposits outcrop on the surface, like the Newfoundland deposits, and can be openly quarried. Other deposits are deep in the earth and are covered by other rock formations. These have to be developed by the sinking of vertical shafts. The principal deposits now being operated are in inclined beds and are mined through slopes following the angles of the dip. When the mines are opened out by shafts or slopes, levels are run and connected together as in coal mines. Then the beds are prepared for working either on the long wall or the pillar and stall system.

The United States oil-shale deposits are widely distributed in Texas, Nevada, Colorado and Utah. The Colorado and Utah deposits outcrop in immense beds which in places are over 150 ft. in thickness. An acre of this shale is estimated to carry about 25,000 bbl. of oil. Many of these deposits can be cheaply worked by quarrying and surface excavation. But many important scientific problems have to be determined before the oil can be commercially extracted from the shale.

The oil shales in America are dissimilar to those of Scotland which have been profitably mined and distilled for many years. In Scotland, the oil shales are distilled in vertical retorts resembling iron blast furnaces. The distilling plants are always erected near the mines to save carriage costs. The shale, when taken out of the mine, is crushed into coarse blocks about the size of an ordinary brick. It is then fed into large hoppers placed above the retorts, but connected with them so that they can be automatically fed. The retorts are large brick and cast-iron stacks into which the shale is fed at the top.

The Bryson retort, used largely in Scotland, is a double shaft retort. It is 34 ft. in height. The bottom part, built of bricks, is 20 ft. high, and the remaining 14 ft. is built of cast iron. Each shaft is 15 x 33 in. in plan at the top and 22 x 56 in. at the base of the brick part. The retorts stand on a base of stone, concrete, or bricks about 20 ft. in height. In other words, the hopper feeds are 63 ft. above the ground. Each retort holds 15 tons of shale. At the base of the brick portion of the retorts there is a revolving cast-iron bottom which stirs up the shale and automatically discharges the spent shale into a hopper and on a revolving belt which takes it away to the spent shale dump. A single retort extracts the oil and ammonium contents from 4 tons of shale every 24 hr. Consequently, to handle 1000 tons daily, it is necessary to provide benches containing 250 retorts. The retorts are fired by gases from the distilling works, augmented by producer gas from coal. The gases given off from the shale are drawn into collecting chambers and passed through ordinary water-cooled pipe condensers made from 4-in. pipes arranged in long vertical stacks. Ammonia water and crude oil are collected in the condensers and drawn into tanks. In these tanks, the water settles while the oil rises to the surface and is drawn off into other tanks and separators. It is found that some of the gas cannot be condensed in the condensers. This is called the permanent gas. It is cooled in an ice machine and compressed in a power compressor. By these means a certain amount of gasoline is secured from it. The remainder of the gas from the compressor is stored in gasometers and is used for fuel purposes.

The crude oil, after being extracted from the shale, is treated as crude oil from oil wells is treated in the refineries. The refining processes and machinery are modified to suit local conditions met with at the different localities. The Scotch method of oil-shale distillation is quite unsuited for American conditions. It is too costly, slow and inefficient. Before the industry can be established here, an entirely new method of retorting must be developed. There must be means provided for handling large quantities of shale. Our inventors and experimenters are recognizing this. A recent patent covers a method for treating the shale in pulverized form in steam-jacketed pipes. The powdered shale is dropped into steel tubes heated with superheated steam. The volatile hydrocarbons are drawn off at different temperatures. By these means, ordinary retorting is avoided. The operation is really a straight distilling and refining operation in a single plant.

Form of Carbon in Shale

The Colorado Geological Survey is experimenting on some of these problems which must be solved before the oil shale industry of the United States can be firmly established. It finds that the Colorado shales appear to carry carbonaceous material in three distinct forms, and therefore require three different retorting operations. These forms are:

(1) True hydrocarbons in the solid form, occupying extremely small pits and intergranular spaces in the shale
(2) Plant, and possibly animal matter, which has undergone changes akin to those by which vegetable matter is converted into coal
(3) Fixed carbon

The relative proportions of these three materials are far from constant. In some rich shales the true hydrocarbons, probably paraffins, greatly exceed the other two materials. Such shales when examined under a powerful miscroscope show great numbers of grains of true hydrocarbons, and very little, if any, vegetable tissue. The fixed carbon content of such shales is generally low. On the other hand, there are shales in which the vegetable tissue greatly exceeds the hydrocarbons in quantity.

In retorting, the true hydrocarbons appear to vaporize at a comparatively low temperature, while a higher heat is necessary to develop hydrocarbon gases from the vegetable matter, and the last hydrocarbon gases are given off at a very high temperature. Whether these last come from the true hydrocarbons or from the altered vegetable tissue it seems impossible to determine. The fixed carbon cannot be converted into hydrocarbon gases unless, in some way, the necessary hydrogen is supplied, and it is doubtful whether the hydrogen and carbon can be made to unite under the conditions prevailing in the retorts. The shales are not simple homogeneous materials yielding their gases by volatilization at a definite temperature or within a narrow range of heat.

Tasmanite shales yield on distillation between 40 and 65 gal. of crude oil per ton and corresponding quantities of ammonium. The oil is very dark and viscous. The mining of tasmanite shales costs about $1.50 per ton and retorting costs 60 cents. The average return is about 40 gal. per ton.

The torbanite and tasmanite shales mentioned together with albertite constitute the three classes into which oil-bearing shales are divided. Albertite is a solidified mineral pitch, dark black in color, like hardened coal tar. The largest deposits of pure albertite occur in Albert County, New Brunswick, Canada. It yields between 90 and 120 gal. of oil, and 80 and 90 lb. of ammonium sulphate per ton. In many parts of the United States, in western Canada, Queensland and New Zealand there are large deposits of sandstones and shales richly impregnated with asphaltum which chemically resemble albertite.

American oil shales cannot be developed on any large scale without the investment of a tremendous amount of capital. Until economic conditions change and force us to utilize auxiliary oil resources, oil-shale developments will be of little commercial interest.—A. Selwyn-Brown in Sinclair's Magazine.

TRUNK HIGHWAYS

THE problem of the design of a highway from the standpoint of traffic resolves itself into a determination of the probable amount and character of vehicular traffic during a future period, the design of the grades, curves and width of the roadway so that it will be efficiently serviceable for the traffic which it is to carry; the determination of the amount and character of external forces to which the different parts of the highway are subjected and finally the design of the bridges, drainage systems, foundations and roadways so that they will have sufficient internal strength to resist the external forces during a reasonable period of time.

The forces, due to motor-truck traffic, which should be given consideration in the design of a roadway wearing course and its substructures are the direct load causing compression, impact forces, the shearing forces of the driving-wheels and the resultant forces between the subgrade and the pavement foundation. Necessarily these forces are functions of the volume, weight, speed and character of the vehicles using the highways. These factors are determined as a result of information furnished by highway transport surveys and legislative regulations covering these factors. The best indication which we have of the probable normal maximum weights of vehicles to which highways will be subjected in the immediate future is the recommendation of a committee of the National Highway Traffic Association which was adopted at the 1919 convention of the American Road Association and which was later incorporated in the proposed uniform vehicle law which is supported by several national organizations. The above recommendation pertaining to motor trucks allows a load per linear inch of width of tire of 800 lb. and a maximum gross load on four wheels of 28,000 lb. These limitations, which have been embodied in the laws of several states, allow the use of motor trucks having a capacity of 7½ tons. In this connection it should be noted that the Trailer Manufacturers' Association of America has advocated legislation limiting the weight on four wheels of a trailer, including the vehicle body and its load, to 28,000 lb. These recommendations give us a definite starting point for the design of pavements and their substructures.

A Minimum Width of 20 Ft.

Although those who have given careful consideration to the probable development of highway transport believe that the economic and efficient development of this form of transportation will not necessitate, for many years, the utilization of motor trucks having a greater capacity than 7½ tons, nevertheless it is admitted that it may be desirable in isolated cases to transport over highways loads on four wheels in excess of the limit prescribed. The transportation of such weights, however, should be provided for by special legislation rather than be accepted as the fundamental basis for design.

This discussion will be limited to a consideration of pavements suitable for interstate and intrastate trunk highways which will be subjected to an intensive motor-truck traffic. The width of the pavement should first be given consideration. Roadways economically designed must provide for carrying the traffic on the paved roadway surface, and not rely upon shoulders to carry a part of the traffic or serve as turnouts. It has been demonstrated that the latter practice is neither economical from the standpoint of the maintenance of pavements and shoulders, nor efficient or safe from the standpoint of the traffic using the highway. In other words, we must provide for a minimum of two lines of commercial traffic, and it is obvious that an operator of a heavy motor truck will insist upon allowing a certain amount of leeway between the outside wheels of the truck and the edge of the pavement, since many operators have had unfortunate experiences with motor trucks being stalled in soft shoulders or ditched. Considering the factors of widths and speeds of passenger cars and motor trucks utilizing trunk highways, and that the laws of many states permit a maximum width of 8 ft. for motor trucks, taken in conjunction with the rapid increase in the volume of traffic on trunk highways, the conclusion is reached that 20 ft. for the width of the pavement surface on a trunk highway should be considered the minimum. There are highways where the normal traffic requires provision for two lines of vehicles, and the abnormal traffic, particularly on holidays, Saturday afternoons and Sundays, will render the adoption of 24 to 26 ft. justifiable. This is due primarily to the fact that provision should be made for vehicles standing at the side of the road while temporarily requiring repairs. While traveling on a highway in the vicinity of Detroit, on a Sunday during July, 18 vehicles parked at the side of the roadway, and under repair, were passed in 15 min. on a 5-mile section. If the transport survey indicated that the normal amount of traffic will require provision for more than two lines of vehicles, a greater width than 20 ft. must be adopted, the additional width depending upon the character of the traffic. It does not require much imagination to reach the conclusion that many interurban highways will be subjected during the next decade to traffic which will necessitate roadways sufficiently wide to accommodate at least four lines of vehicles, which would mean a width of from 38 to 48 ft.

Construction Materials

For the classes of trunk highways under consideration, the roadway wearing course should be composed of a brick, plain or reinforced cement-concrete, bituminous concrete, sheet asphalt, wood block or a stone block pavement supported by a reinforced concrete, plain cement-concrete, bituminous concrete or heavy stone foundation. The selection of the particular type will depend upon many local economic factors and the results of the transport survey.

The highways outside of our municipalities have had a changeable status in the last 30 years, and the reasons advanced for their improvement have been many and varied, but mostly sound. Fortunately there has been rapidly developing throughout the land a conviction that highways are merely a means to an end and that end is the economic and efficient transportation of passengers and commodities. It has also become self-evident that unimproved and improperly built highways constitute a positive barrier to the development of economic highway transport. In order that highway transport should take its proper place in our transportation system, the following fundamental guiding principle must be accepted generally: Highways should be designed, constructed and maintained so as to enable them to carry efficiently the motor vehicles required for the rapid development and economic utilization of highway transport.—A. H. Blanchard in *Michigan Manufacturer and Financial Record.*

The Relation of Recoverance to the Fatigue of Metals

By Robert G. Guthrie[1]

Illustrated with Photograph and Chart

RECOVERANCE is a name representing a property which is inherent in all matter. The measurement of recoverance is made possible by the use of a testing machine called a Modulimeter, which is shown in Fig. 1. Extensive research on recoverance has been carried on at the laboratories which I represent, with a view to relating the recoverance values of various materials with the fatigue, wear, and durability values of these materials so that the adaptability and quality of any material for any specific purpose can be determined in simple understandable terms and by simple quick tests.

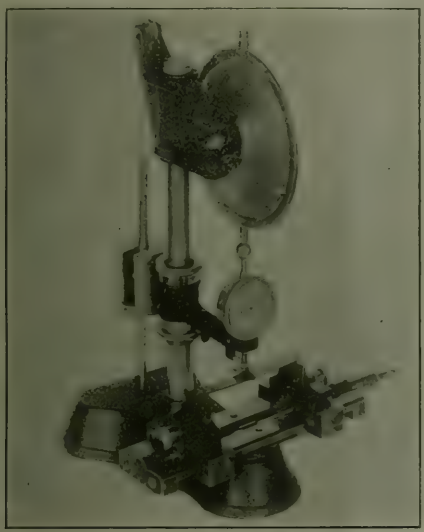


Fig. 1—An Instrument Designed to Test the Recoverance of Various Materials

The general definition of recoverance is stated as the capacity of a material to return *immediately* the energy that has been imparted to it by any external force. In other words, when the molecules of a material are forced by compression, tension or bending, from their relative normal position, the force immediately exerted by these molecules after the disturbing force is removed, in their return toward their normal position, is the recoverance of the material.

The recoverance figures given represent a percentage, depending upon the areas beneath the loading and unloading curves. These figures are, in reality, manifestations of the rate of recoverance, which is the all-important factor regarding fatigue. Because no mechanism is available that is capable of recording a recoverance curve, or the rate of recoverance, following the instantaneous removal of the total load, the plotting of a recoverance curve under a series of loads is necessitated. These curves, however, will be the same whether they are the result of the application of one load and its removal, or the result of this same amount of load applied in several increments and removed in successive decrements.

In a curve plotted automatically, covering the action of the material under a cycle of stress or repetitions of such cycles, the unloading line will diverge from the loading line in exactly the same way as one plotted under load. But, in plotting the curves under load, the complete cycle of loading and unloading is stopped during its course at definite points represented by the weight of each increment, and the deflections are noted. After this material has been loaded to any predetermined number of increments within its elastic limit and any of these increments have been removed, a point is reached which does not coincide with the corresponding point on the loading line. A loss then is represented by the divergence of the unloading from the loading line and, as long as this particular load remains upon the material, this distance will represent a total loss in strength to the material. If, however, the total load is removed at one time, similar

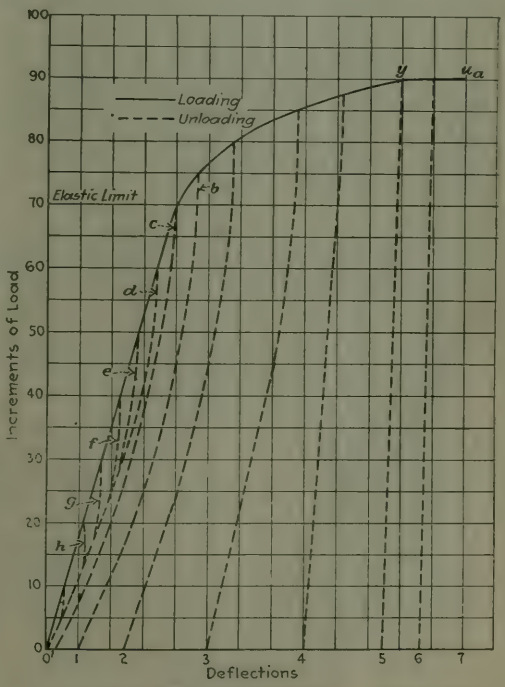


Fig. 2—Chart Showing the Recoverance of a Specimen That Has Been Subjected to Repeated Loads

[1]A. S. A. E.—Director of tests, Widney Test Laboratories, Chicago.

to the removal of the load during repetitions of stress, this curve will not stop at any of these points but will pass through them on its course back to the origin, *O*, in Fig. 2 on page 65. It then follows that, whatever the recoverance figure may be, the rate of recoverance will be directly proportional; i. e., if the curve of a material is plotted under load and a definite recoverance noted such as 80 per cent and another graph is plotted covering a different material, showing a recoverance figure of 70 per cent, it will then follow that the material showing the recoverance value of 70 per cent is lower by 10 per cent in recoverance, and also lower by 10 per cent in the *rate* of recoverance. In other words, all of the unloading lines in Fig. 2 show that the greater the distance to be traversed is, the greater the time is that will be required to traverse it, for the reason that they are curved lines. It then follows that the lower the percentage of recoverance is, the lower is the rate of recoverance; and that the higher the percentage of recoverance is, the higher is the rate.

The three distinct types of recoverance are produced by bending, tension, and compression. This paper deals only with recoverance produced by bending. The determination of recoverance on the modulimeter shown in Fig. 1 on page 65 is accomplished in the following manner. A metal sample 0.05 x 0.25 x 6 in. in dimensions is ground and polished and placed on knife-edges 4 in. apart. A gage graduated to 0.001 in. is directly connected to the plunger, which in turn is directly connected to the third knife-edge, equidistant from each of the supporting knife-edges. Equal increments of load of either 50 or 100 grams (1.76 or 3.52 oz.) each, depending upon the material, are placed on a platform carried by the plunger, which carries the third knife-edge. A predetermined load is applied in successive equal increments; i. e., if the predetermined load is to be 1000 grams (35.2 oz.) it will be applied in either twenty 50-gram (1.76-oz.) increments or ten 100-gram (3.52-oz.) increments. The deflection reading is noted after each increment. Likewise, when each decrement is removed the corresponding deflection is noted. The resultant then is a loading curve and an unloading curve. The ratio of area beneath the unloading curve to the total area under the loading curve gives the percentage of recoverance.

Fatigue

The recoverance of a material is a direct indicator of the ability of the material to withstand fatigue, but recoverance alone is not a conclusive measure of the susceptibility of a material to fatigue.

Referring to Fig. 2 on page 65, Curve *k*, the material is loaded to 20 increments, giving a certain deflection. This material is then unloaded and a slight loop is developed, although the material comes back to the point of beginning after the load has been removed. Subtracting the area of this loop from the total area underneath the increment curve gives the recoverance area. It will be noticed from this loop that the loading line and the unloading line do not coincide throughout their lengths. This is a manifestation of the fact that there is a loss when the material is gradually loaded in successive equal increments and unloaded in exactly the reverse order. The unloading line does not return to the same points on the loading line, although, if the total stress applied is within the elastic limit, the last point will be at the point of beginning, as previously stated. It is obvious then that, when a material is subjected to repeated stresses, there will be as many of these loops formed as there are complete cycles of stress. Inasmuch as the area bounded by a loop represents a loss in strength to the material, it is obvious that, providing the rate of repetitions of stress is greater than the rate of recoverance, a certain percentage of this loop will be held over from one repetition to the next. As the repetitions continue, the magnitude of this loop would naturally increase much as is shown in Fig. 2 by Curves *g*, *f*, *e*, *d*, *c*, *b* and *a*, until Curve *co*[1] is reached. This curve would not come back to the origin *o*, and, consequently, at this curve the elastic limit will have been reached and the material will have taken a permanent set. The loss then will not only be by the divergence of the unloading line from the loading line, which loss, were it in any curve such as Curves *d* or *e*, would be recoverable and would depend on a time factor, but there will be also a permanent loss represented by the distance *oo*[1], a small part of which may be recoverable over a period of time due to recoverance beyond the elastic limit. Provided these repetitions of stress were continued, the point

Table 1—Test of Standard Samples on Type X Machine, as Listed[2]

Series No.	Sample Material	Number of Increments	Recoverance Values, per cent						Stiffness		
			Test 1	Test 2	Test 3	Range	Average	After 3-hr. Rest	Deflection in 0.001 in.		Average, per cent
									Test 1	Test 2	
1	Cast Iron, No. 1	5	89.0	92.0	84.5	7.5	88.5	93.2	0.056	0.0505	37.5
2	Cast Iron, No. 2	5	93.6	95.0	97.4	3.8	95.3	93.5	0.044	0.0420	46.5
3	Cast Iron, No. 3	5	93.6	94.0	94.0	0.4	93.8	91.0	0.058	0.0635	32.8
4	Steel, No. 1	10	100.0	100.0	....	0.0	100.0	100.0	0.020	0.0200	100.0
5	Pure Swedish Bar Iron, No. 1	10	98.0	99.2	99.4	1.4	98.8	94.0	0.025	.....	80.0
6	Cast Brass, No. 1	8	98.5	98.4	98.6	0.2	98.5	97.9	0.051	0.0500	39.6
7	Cast Brass, No. 2	8	97.9	98.4	98.9	1.0	98.4	96.9	0.056	.....	35.7
8	Rolled Brass, No. 1	10	99.5	99.8	99.7	0.3	99.6	96.8	0.033	0.0330	60.6
9	Rolled Brass, No. 2	10	99.6	99.8	99.8	0.2	99.7	99.4	0.035	0.0350	57.1
10	Cast Aluminum, No. 1	5	98.5	99.1	99.6	1.1	99.0	98.4	0.084	.....	23.9
11	Cast Aluminum, No. 2	5	99.6	99.1	99.1	0.5	99.2	....	0.064	.....	31.2
12	Rolled Aluminum, No. 1	5	100.0	99.3	99.3	0.7	99.5	99.4	0.054	.....	37.0
13	Rolled Aluminum, No. 2	6	98.4	98.8	99.5	1.1	98.9	93.0	0.049	.....	40.8

[2]Dimensions of each sample, 0.05x0.25x4.875 in.; knife-edges at 4-in. span; weight of each increment, 3.8 oz.; all stiffness tests made under a five-increment load.

TABLE 2—TESTS OF STANDARD STEEL SAMPLES ON TYPE X MACHINE

Series No.	Sample Number and Condition						Distance Between Centers, in.	Number of Increments	Weight of Each Increment, oz.	Recoverance Values, per cent					Average of Regular Tests, per cent
	As Is	Burned	Magnetized Side X	Badly Burned in Forge	Ground and Slightly Annealed	After Burning and Deformation				Rest Test	Regular Tests				
											1	2	3	4	
1	No. 3	....	....	....	....	....	4	5	14.7	97.5	99.5	99.8	99.9	98.5	99
2	....	No. 3	....	....	....	....	4	5	14.7	90.3	96.2	95.5	96.2	....	95
3	No. 4	....	....	....	....	....	4	5	14.7	100.0	100.0	100.0	100.0	....	100
4	....	....	No. 4	....	....	....	4	5	14.7	97.4	99.4	100.0	100.0	....	99
5	....	....	....	No. 5	....	....	4	5	3.5	92.0	96.3	94.8	96.5	....	95
6	No. 6	....	....	....	....	....	4	5	14.7	90.8	98.6	99.4	99.0	....	99
7	....	....	....	....	No. 6	....	4	5	14.7	.....	100.0	99.9	.....	....	99
8	....	....	....	....	....	No. 6	4	5	14.7	97.8	98.9	98.4	98.5	....	98

a would finally be reached, at which point the decrement line would cease to exist and this point would be the ultimate failure of the material or the fatigue ultimate. It must be remembered that Fig. 2 does not show all of the cycles of stress with their percentages of recoverance held over to the next time, but merely the succession of hysteresis loops to illustrate the theory of the foregoing. These curves were not plotted from an actual test on one material, but were compiled from numerous tests on various metal bars.

The definition of fatigue as given in Merriman's Mechanics of Materials is "the loss of molecular strength under stress often repeated." The recoverance mentioned in this paper is the result of stress within the elastic limit. Fatigue ultimate is the point at which failure occurs when a material has been subjected to oft-repeated stresses within its elastic limit. The direct factors in fatigue are the number, frequency and magnitude of stresses. It follows then that any material will develop fatigue and ultimately fail when the rate of repetitions of stress of any magnitude, within the elastic limit, is greater than the rate of recoverance. Conversely, there will be no fatigue when the rate of repetitions of stress of any magnitude, within the elastic limit, is less than the rate of recoverance. There is, however, a recoverance beyond the elastic limit, but no explanation of that will be given in this paper.

Where a difference in recoverance exists between two metals either similar or dissimilar, amounting to less than 1 per cent, it can be neglected and the metals characterized as having the same recoverance. As there should be a comparable difference in the recoverance of two metals if they are to be described as metals having different recoverance values, a difference of 1 per cent is established as a comparable recoverance difference in metals; that is, any metals not having a difference, one from the other, greater than 1 per cent will be classified as having the same recoverance. As shown in Table 1, Series 4, steel has an average recoverance of 100 per cent, whereas in Series 5 the average recoverance of pure Swedish bar iron is 98.8 per cent. The difference then is 1.2 per cent. It is thus obvious that these two metals have different recoverance values.

Referring to Table 2, Series 3 and 4, the tests on these samples show 100 per cent recoverance in the former and 99.4 per cent in the latter, the difference being 0.6 per cent. Consequently this metal was practically the same before it was treated as afterward.

ANOTHER THEORY OF RECOVERANCE

A further theory regarding recoverance as applied to metals and theories regarding the reasons for recoverance can be advanced, although it is not expected that these theories will be accepted first-hand as absolute facts. But they are the natural conclusions to be inferred from data at hand.

The recoverance of a metal is governed by its chemical and physical homogeneity, and to a certain extent by its fineness of structure. In other words, if it were possible to obtain a metal of a solid solution and approaching a non-crystalline stage, it would follow that this material would have an extremely high recoverance and a high

TABLE 3—TESTS OF STANDARD STEEL SAMPLES ON TYPE X MACHINE[2]

Series No.	Sample Number and Condition			Dimensions, in.	Distance Between Centers, in.	Number of Increments	Weight of Each Increment, oz.	Recoverance Values, per cent				Percentage			Average Recoverance, per cent
	As Is	Normalized	Quenched					Test No. 1	Test No. 2	Test No. 3	Test No. 4	Maximum	Minimum	Range	
1	No. 1	....	....	0.05x0.25x4.875	2	5	14.7	100.0	100.0	98.0	....	100.0	98.0	2.0	99.3
2	No. 1	....	....	0.05x0.25x4.875	3	5	14.7	97.0	100.0	97.6	....	100.0	97.0	3.0	98.2
3	No. 1	....	....	0.05x0.25x4.875	4	5	14.7	99.1	96.0	98.5	....	99.1	96.0	3.0	97.8
4	....	No. 2	....	0.05x0.25x4.875	4	10	3.8	99.0	98.2	97.7	....	99.0	97.7	1.3	98.3
5	....	No. 2	....	0.05x0.25x4.875	4	5	14.7	97.9	98.7	99.0	99.0	99.0	97.9	1.1	98.6
6	....	....	No. 2	0.05x0.25x3.375	3	5	14.7	96.3	96.4	92.0	....	96.4	92.0	4.4	94.9

[2]All tests made with knife-edges.

fatigue value. Metals have been found averaging 100 per cent recoverance on the instrument mentioned, but 100 per cent recoverance absolute is not possessed by any material. This 100 per cent recoverance figure is obtained on an instrument which is not mechanically perfect. If it were possible to measure the recoverance of any metal on an instrument of the nature of the ultra-microscope and capable of infinitely finer work, it would be found that this material would not have a 100 per cent recoverance.

The statements regarding chemical and physical homogeneity and fineness of structure are exemplified in Table 1 on page 66. Steel sample No. 1, Series 4, which was in the sorbitic condition and showed every evidence of an excellent structure, tested 100 per cent recoverance. The obvious opposite of this material is a grey cast iron shown in Series 1, 2 and 3. These were three samples cut from the same bar. Comparing the average of their three recoverance averages with the average recoverance of the steel, the difference in 7.5 per cent. Further, the range of the three tests of cast iron No. 2, Series 2, is 3.8 per cent; whereas, in Series 3, cast iron No. 3 has a range of only 0.4 per cent, and in Series 1, cast iron No. 1 has a range of 7.5 per cent. It is obvious that this cast iron is extremely variable as regards recoverance and stiffness, which is no more than should be expected from a bar of this material.

Again referring to Table 1 on page 66, Series 10 and 11, the average recoverance of the aluminum is practically that of steel No. 1, Series 4. According to the theory, this would be expected. The aluminum was of good quality and, although not of the fineness of structure of the steel, they are somewhat related as regards their chemical and physical homogeneity. It will be noticed also that the stiffness values in the last column are only ¼ and 1/3 those of steel No. 1, Series 4, notwithstanding the fact that the recoverance is practically the same. In the case of Series 5, the Swedish bar iron showed a recoverance comparably less than that of the steel, but approximately that of the aluminum; and, contrary to the comparison of the aluminum and the steel, which showed practically the same recoverance and a very low stiffness value, the Swedish iron has a very much higher stiffness value than any of the aluminums, but the recoverances are almost the same. In the case of the rolled brasses, Series 8 and 9, the recoverance is practically the same, as is their stiffness. The recoverance of the cast brasses in Series 6 and 7 is almost the same, as is their stiffness, but the stiffness of the cast brass in Series 7 is only about one-half that of the stiffness of the rolled brass in Series 8; the difference of their recoverances is, however, only 0.2 per cent over the limit set as a comparable difference.

The metals tabulated in Table 1 on page 66, have, as a whole, practically nothing in common as regards their so-called physical properties, with the possible exception of their structure as revealed under the microscope. It is meant by this that the physical properties of a presumably pure cast aluminum, Table 1, Series 11, and of a sorbitic steel, Series 4, are exceptionally far apart as regards their tensile strengths, elastic limits, elongations, reductions of area and the like, but that the aluminum as an elemental metal is approaching the state of chemical homogeneity, and that the steel in Series 4 is approaching the same state as a solid solution. Although their structures are somewhat different physically, it is evident that the further these metals get away from the mechanical mixture state, the higher will be their recoverance. This must not be construed to mean that aluminum can be used in the place of steel simply because their recoverances are the same or nearly so; but that, from any given number of bars of like material, the one highest in recoverance should be chosen for parts subjected to fatigue.

In the column showing 3-hr. rest tests, Table 1 on page 66, in all instances except Series 1, 4 and 12, the recoverance value of a rest test is considerably lower than that of a regular test. In this rest test, the material was tested after it had not been subjected to any external stresses for from 3 to 24 hr. The first test on each bar under these conditions was characterized as the rest test. The three regular tests followed as soon as possible. In many instances, as shown in Series 3, 5, 8 and 13, the rest test recoverance was much lower than in the lowest regular test.

The hypothesis submitted regarding these rest tests is that when the material is at rest the molecules possess potential energy but, due to this state of rest, it is not necessary for these molecules to change this energy from the potential to the kinetic state. In other words, there is no greater amount of energy possessed by the molecules during the regular tests, or after they have been disturbed, than before; but there is a greater outward manifestation of the energy that is inherent in the molecules, due to the excitation by external force of their intra-atomic and intra-molecular activity. If this line of reasoning be carried still further, it can be said that a super-excitation of this intra-activity is produced which increases in magnitude and intensity with the increase of external stress until a point is reached where this internal strain or intra-activity is so intense that the molecules disrupt themselves. This causes an outward manifestation either across or along the planes of the crystals and still more apparent manifestations of probably a microscopic nature inter or intra-granular and, finally, a complete failure of the material under stress.

It is sometimes noticed that the path of a fissure may be either intra or inter-crystalline. This is evidently due to (*a*) what might be characterized as a series of weak or damaged crystals, an explanation of the existence of which will not be attempted in this paper; or (*b*), according to the present train of thought, highly localized intra-activity which in turn will follow as a natural consequence from the aforementioned weak crystals. The unit intensity or localization of this super intra-activity is evidently made possible by the original set of weak crystals.

The curve mentioned in the following paragraphs and shown in Fig. 2 on page 65, Curve *c*, which can be called for convenience one of stress-strain equilibrium, would start to fall rapidly at the point where the strain or intra-activity begins to be disproportional to the external stress or, in other words, where the rate of intra-activity begins to be greater than the rate of recoverance, which would be its elastic limit. This molecular power must be very great, because considerable work must be performed upon a material before it will ultimately fail as it does in a fatigue test. If a curve of this internal molecular resisting force could be plotted, it obviously would start very slightly below its peak, rise abruptly from this point to the peak and continue in practically a straight line, very slightly dropping toward fatigue ultimate for an infinite distance. The measure of the fall and length of this peak line would be determined by the rate of repetitions of stress, regardless of their individual magnitude, and the magnitude, provided it were great enough regardless of the rate of repetition. It should be possible under ideal conditions for a point of equilibrium to be established wherein the magnitude and rate of repetitions of stress would be exactly equal to the rate of recoverance. Then this line, other things being equal, would continue as an absolutely straight line to infinity.

Scientific Work of the Government[1]

By E. B. Rosa[2]

THE Federal Government, having emerged from participation in the world war, finds itself with a large debt and heavy annual charges caused by the war. These, together with the current cost of the Army and the Navy, amount for the present fiscal year to 92.8 per cent of the total budget. The cost of public works and the necessary administrative cost of the Federal Government amount to 6.2 per cent of the total. There remains 1 per cent for a large number of governmental activities classed as research, educational and developmental. The question arises whether in the interest of economy and efficiency the 1 per cent shall be decreased; or, because this work is constructive and of great economic value, whether it shall be increased and possibly doubled.

The Government should be constructive and helpful to the people and to business wherever possible. It should carry on scientific research, promote education, develop the industries, assist in improving commercial and industrial methods and furnish technical information to manufacturers and others, as well as develop agriculture and the public domain. Such service by the Government tends to establish good relations with business, elevate business methods, increase efficiency and educate the public. The many services thus rendered cost very little in the aggregate as compared with the total expense of the Government. One per cent of the total expenses of the Government spent in this constructive way seems a very small proportion in view of the wide range and the economic value of such work.

A part of this 1 per cent is incurred in behalf of the Government itself, to enable it to purchase its supplies intelligently and to do business in a businesslike way. Without this research and testing work the Government would waste more in buying than it would save by eliminating the research and testing. Making purchases without full technical information is embarrassing to public officials and unsatisfactory to business; whereas by always using intelligently-drawn specifications and making adequate tests, the Government can save money, elevate its own service and improve business methods. Much, but not enough of this kind of work is now done. It is the duty of the Government to set a good example of efficient and intelligent methods and fair dealing; neither accepting goods below the specified quality nor demanding more than is specified. The Government would spend less for its purchases if it spent more in standardizing the products purchased and in testing deliveries systematically.

Apart from the service the Government can render its citizens and the benefit to the State resulting from scientific, educational and developmental work, and apart from the benefit to the Government of having the results of such work in constructing buildings and other public works, and in carrying on its business, this kind of work develops wealth. Economizing in the use of raw materials, using cheaper materials, reducing waste, developing the public domain. increasing manufacturing efficiency and reducing distribution costs, all tend to create wealth and to make it easier for the Government to raise needed revenue.

To check rising prices and, if possible, bring down prices, it will be necessary to increase production. To do this it is necessary to reduce waste and increase efficiency. This requires greater intelligence and fuller knowledge, and calls for education, the results of scientific investigation and of intelligent and extensive industrial research. The Government could not and should not do it all. But neither should it refuse to do its part, and its part often is to take the lead in a constructive and statesmanlike way. It is stupid and blind to think that because taxes are heavy we cannot afford to do things intelligently. Intelligent research by the Government stimulates production, increases wealth and pays for itself many-fold. It is as productive and profitable in peace as in war.

The development of our intellectual, moral and material resources, is the best preparation for war. Food and manufacturing facilities, adequate supplies of raw materials and transportation systems, scientific attainments, the equipment and trained personnel available for military research, together with an intelligent citizenry and a just cause, are the best preparation for war. A standing army and fleets of battleships are necessary but not a sufficient preparation. A government that pays much attention to education and research and industrial developmental work is making the best preparation for possible wars of the future. This fortunately produces good results if war never comes. Increasing the power and prestige of the nation tends to prevent war. We should strive for a higher and truer efficiency in the Government, in labor and in business.

[1]From a lecture before the Washington Academy of Sciences.
[2]Chief physicist, Bureau of Standards, Washington.

ENGINEERING MUSEUM

WHEN will the great Museum of Engineering be started in America? For anyone who knows the importance of engineering it is a great pleasure to see that in the National Museum in Washington the famous Stevens marine engines and many other masterpieces of engineering are accorded equal prominence with other exhibits. What Paris can boast of in its Conservatoire des Arts et Métiers, London in its Kensington Museum, and Munich in its German Museum will surely in no distant future be emulated by a country which has risen into prominence with steamships and railroads and through the achievements of engineers who are famous throughout the civilized world at the present time.

The science of engineering is not confined to the boundaries of any one country, and as in Munich the masterpieces of the different nationalities are placed peacefully side by side, so the future great American Engineering Museum will no doubt bear testimony to the fellowship of all engineering and scientific research workers.—C. Matschoss in *Engineering News-Record.*

RAILROAD VALUATION

THE Interstate Commerce Commission began to appraise the railroads in 1914, and is about half done with the job. It estimated the value of the roads to be $17,525.000,000 on June 30, 1916. In the recent rate decision the Commission fixed the value of the railroads at $18,900,000,000, which is more than its estimate of 1916, and yet is $1,716,000,000 less than the total presented by the roads themselves.—J. C. Marquis.

SHALE OIL

IN 1913 the Bureau of Mines began to investigate the oil shale deposits in Colorado, Utah, Nevada, Wyoming, Montana and California, primarily to lay the predicate for segregation of land and secondarily to ascertain the extent, character and commercial value of the deposits. Dean Winchester conducted the field work of testing the shales and arriving at approximate values and the location of the best deposits. When enough had been known to indicate the major deposits, two areas in Colorado and Utah, uniting practically as one, were withdrawn as naval reserves for oil, about 86,000 acres altogether. Mr. Winchester's investigations and tests were incorporated in Government reports. Over 100 companies were organized by residents of the states in which shales are found, beginning three or four years ago. Some of the companies began preparations to put up demonstration plants in Salt Lake and Denver, and finally to move some material to the locations of their leased or fee acreage, notably near De Beque, Col.

Efforts were made to learn about the shale oil plants that had been operating in Scotland 50 years, and the Scotch processes were generally accepted as the basis for further experimentation and modified demonstration. For two or three years there was considerable activity. There is not a plant in the United States that is turning out shale oil, either crude or by-products, and every one that is active is experimenting. The processes that are being worked on for successful adoption by the trade are known as the Galloupe, the Genet, the Jenson, the Sundberg-Lichliter-Winter, the O'Rourke, the Stallman, the Catlin, the Day and perhaps two or three others. The Henderson or Scotch and the DeBry or French principles of retorting form the base of all experiments, probably because they have been successfully employed in commercial plants. This is especially true of the Henderson processes used in Scotland. So far as it is known, only six plants are now active; one at Elko, Nev.; one at Dillon, Mont.; one at Salt Lake and one at Dragon, Utah, and two at DeBeque, Col. There is one plant at Elko, two at Salt Lake, one at Watson, Utah, and several at DeBeque district that are inactive.

Shale oil is contained in solid sedimentary substances deposited through still water on the bed of the body of water and formed from marine life, organic and inorganic. The ore must be mined, crushed and run into a retort, where it is superheated until the gases or vapors are thrown off and conveyed through pipes to a condenser, where it becomes a black, heavy and viscous fluid of rank odor. As mere crude oil, thus run off, it does not appear to be as valuable as crude petroleum. Treated in a standard petroleum refinery the results are problematical. If gasoline, naphtha, kerosene, lubricating oil and paraffin wax are desired for commercial profit, superficially it seems that petroleum is more amenable and valuable than shale crude oil. Analyzed by ordinary scales, petroleum appears preferable to shale oil.

The chemists and engineers who have delved deepest into shale and its derivatives are fairly agreed that direct methods of precipitating and stabilizing its ingredients, as with crude oil petroleum do not yield satisfactory results. Oil shale is complex and reflex, and must be treated synthetically, if experiments to date indicate anything. Experimentation has progressed far enough to determine beyond doubt that oil shales are like petroleum, gold, copper, or any other natural product, in that they vary in quality and content quantity almost as frequently and unexpectedly as petroleum oil sands. Some shale will yield only a gallon of crude oil, some will yield 10 gal., some will yield 20 gal. and up to 30 or 40 gal. per ton. The Bureau of Mines Experiment Station at Salt Lake has found none passing through its retorts that yielded more than 65 gal. per ton, and very little that ran that high. A barrel of 42 gal. per ton, with all the data at hand, is a maximum average that probably will not stand up in commercial operation the country over.

Some shales that produce 42 gal. of oil per ton, when that crude oil is very low grade, would be worth no more than shale producing 5 gal. of high-grade oil. Shale oil varies in gravity and distillate content as widely as crude petroleum differs in gravity and content, or as natural gas varies in gasoline content. Crude shale oil shows a Baumé gravity rarely exceeding 23 deg., indicating a low place in the light distillate scale. No one expects to secure much gasoline or other valuable distillates from 20-gravity crude petroleum, not even ordinarily very much true lubricant, because the manner of its formation and deposition in the lower scales of liquid hydrocarbons was unfavorable.

After a fairly comprehensive investigation of the fields and plant equipment, I am inclined to believe that a commercial industry of importance and reasonable profit to those who engage in it intelligently and efficiently will be established. This result will come not because oil shale must replace and displace petroleum or because it is better and more valuable than petroleum, but because it provides an avenue for capital to be profitably employed.

It appears that the Kentucky shales of the oil-bearing variety are fundamentally the same as Rocky Mountain oil shales, all being of perfect sedimentary deposition, which means at the bottom of water bodies, and of marine origin, geologically. Trenton rock strata in Ohio, Indiana, Kentucky and Illinois are of that geologic period and origin, just as Rocky Mountain shales, now on top of everything, were at one time the bottom, the sedimentary floor, catching the drippings, good, bad and indifferent, heavily saturated with organic and inorganic marine life, largely fish and amphibious and aquatic animals and birds, saturated with salt water, gypsum, sulphur and oxidations from other minerals. Fundamentally, therefore, a reasonable conjecture would be that any mixture formed in such circumstances is not as clean and specifically fixed in its predominating elements as petroleum from washed and crystallized sands and limes. After many years of testing it is known fairly well that petroleum produced from soft and muddy formations along the coast and of heavy gravity cannot be made to yield quantitative and qualitative fractions that exist in the hard, crystallized sand strata of the higher interior regions.

It was almost half a century after petroleum became a commercial industry before gasoline became a dominant factor. Likewise it is likely to be some years before oil shale comes to a clear recognition of its commercial place and value. If it should be classified as a low-grade ore useful in low-priced industrial processes, it inevitably cannot maintain an exaggerated claim to a place among the aristocracy of hydrocarbons.—H. L. Wood, in *National Petroleum News.*

GRAND CENTRAL TERMINAL

THE Grand Central terminal in New York City is a remarkable civic development for which there is no precedent. Although its traffic capacity has by no means been reached and the development of the whole is still incomplete, the terminal is used daily by 50,000 to 100,000 people besides 111,040 arriving and leaving on trains. One of the surprises to the management is the result of actual counts of people who do not use trains but still pass in and out of the terminal. Of the daily train passenger traffic about 65,480 are suburbanites, and this portion of the traffic is steadily increasing. The number of passengers in and out of the station on trains in 1903, at the beginning of reconstruction, was 16,135,667, or 44,200 per day, as compared with 32,338,053 in 1919, or 88,500 per day.—*Engineering News-Record.*

ACTIVITIES OF THE SECTIONS

Sections Calendar

BUFFALO

Jan. 18—The Use of Technical Motion Pictures in Engineering by T. R. Fessenden

CLEVELAND

Jan. 28

DAYTON

Jan. 18—Dinner and Organization Meeting Engineers Club 6 p. m. Technical Session 8 p. m.

INDIANA

Jan. 4—Maj. T. H. Bane

METROPOLITAN

Jan. 20—Service by Cyrus J. Rankin. Visit to large New York Service Station

MID-WEST

Jan. 7—Scientific Cushioning in Truck Design by Charles O. Guernsey.

MINNEAPOLIS

Jan. 5—Future Outlook for the Tractor

Feb. 2—Fuels

Mar. 2—Good Roads and Equipment

Apr. 6—Tractor Service and Repair Equipment

PENNSYLVANIA

Jan. 18—Afternoon—Trip to Navy Yard
Evening—Story of Petroleum film

WASHINGTON

Jan. 7

Feb. 4

At the last meeting of the Council the formation of the new Washington Section was approved upon the recommendation of the Sections Committee. Previous to this action the Washington members of the Society had held a meeting at the Cosmos Club which was attended by 35, notwithstanding the fact that the American Petroleum Institute gave a dinner and the Federated American Engineering Societies had a smoker on the same evening. Those who attended had the pleasure of hearing Capt. St. Clair Streett, who was in command of the Alaska Flying Squad, tell of the experiences of his party in their flight to Alaska and return. This flight, to which too little attention has been given, constituted perhaps a greater test of not only the dependability of the machines employed but also of the nerve of the operators than did even the transatlantic flights. Captain Streett's endorsement of the Liberty engine, with which his plane was equipped, was whole-hearted and sincere. His remarks should encourage very much those who believe in the destiny of American aircraft. Coker F. Clarkson, general manager of the Society, gave an informal talk on the origin, accomplishments and aims of the Society. A number of the members expressed the need of regular gatherings in Washington of those interested in the automotive field with the end in view of not only increasing their technical knowledge but also of meeting other men in the profession in a social way.

It is expected that the Section will in a large part constitute a connecting link in the research work in which the Society and various Government departments are particularly interested.

The election of the following temporary officers is a guarantee of the success of the Section:

Chairman, Dr. H. C. Dickinson
Vice-Chairman, Col. F. H. Pope
Secretary, Archibald Black
Treasurer, C. H. Young

Those desiring to join the Section may do so by communicating with the Secretary, Archibald Black, whose address is Evening Star Building, Washington. Meetings of the Section are scheduled to be held at the Cosmos Club on Jan. 7, Feb. 4, April 1, and May 6. Particulars as to subjects and speakers may be obtained from Secretary Black.

The Indiana Section turned out in goodly numbers on Dec. 1 for an informal dinner, after which a paper on high-speed engines of small piston displacement was presented by C. W. Van Ranst. The deplorable fatal accident suffered by Gaston Chevrolet prevented the attendance of his brother, Louis Chevrolet, who was a co-author with Mr. Van Ranst.

Due to pressure of business which requires his time, Chester S. Ricker has resigned the chairmanship of the Indiana Section. The Governing Committee has elected Lon R. Smith to fill the vacancy for the unexpired term.

The Annual Meeting at New York City during Automobile Show Week will draw perhaps a larger attendance than ever before. Although the automotive industry in common with all others is at present in a period of readjustment, the value of the engineer was never more felt. There never was a time when the services of the engineer were more needed. Cars and automotive apparatus in general of good design which are economically manufactured have a great advantage in the world's markets. When it is realized that the engineer is responsible for both design and production, his importance in the present situation will be universally accepted. It is fitting therefore that the manufacturing companies now more than ever before insist upon the attendance of their engineers at the 1921 New York Automobile Show and the 1921 Annual Meeting of the Society.

The Cleveland Section will run at least two special cars to New York on Sunday, Jan. 9. These cars will leave Cleveland at 7.20 p. m. Those who desire to go with their local Section should write or telephone the Secretary of the Section, A. E. Jackman, 1900 Euclid Avenue. Other special cars will be run from Chicago and from Detroit. Details of arrangements may be had from L. S. Sheldrick, secretary of the Mid-West Section, 333 South Dearborn Street, Chicago, and from M. H. Cox, secretary of the Detroit Section, 1361 Book Building, Detroit.

All members of the Society in Dayton or vicinity are urged to attend a dinner at the Engineers Club in that city on Jan. 18, at six o'clock, at which the establishment of a Dayton Section will be discussed. Considerable interest in this project has already been shown by members in Dayton, and this meeting should bring together all of those who believe in the need of a Section there. It is believed that such an organization, working in conjunction with the highly successful Engineers Club, can do much toward disseminating engineering knowledge and the results of the research work conducted in Dayton territory. After the consideration of the Section organization, the members will listen to a technical paper for which arrangements are being made by the committee.

The Boston Section which was organized in September with 27 members, now has over 50 on its rolls. This confirms the fact that the organization was fully warranted. The Section met on Nov. 19 at the Engineers Club for dinner and later listened to a paper by E. Southworth Church on The Car the User Wants. Mr. Church treated the subject from his experience in automobile sales work. He feels that the day of the heavy uneconomical car is past and that the light machine of good design will more thoroughly meet the public demand.

The discussion of the paper indicated that very many people agree with the opinion expressed by the author, although the contention was made that the engineer must frequently modify his design in view of price limitations and production requirements. Most of the discussion centered around body and chassis construction and spring suspension.

Benjamin F. Bailey, professor of electrical engineering at the University of Michigan, addressed the Detroit Section on the evening of Dec. 17 on Starting, Lighting and Ignition. A buffet supper was served before the reading of Professor Bailey's paper. Moving pictures on the subject were a part of the evening's program.

On Dec. 1 Archibald R. Crawford talked to the members of the Minneapolis Section on the Present Status of the Tractor Industry, considering the subject from the standpoint of the manufacturer, the dealer and the user. He pointed out the necessity of educating the dealer and through him the farmer in tractor economics, and stated that the law of the survival of the fittest is now being applied to tractor manufacturers. On the same evening C. S. Moody gave a paper on the treatment of plain carbon and alloy steels for use in tractor construction.

The January meeting of the Mid-West Section will be held on the 7th. Charles O. Guernsey, chief engineer, Servic Motor Truck Co., will speak on Scientific Cushioning in Truc Design.

The Metropolitan and Pennsylvania Sections held a join meeting on the afternoon of Dec. 14 prior to the Moto Boat Meeting of the Society. The members of the Pennsy vania Section were met upon the arrival of their train fro Philadelphia by a committee of Metropolitan Section mem bers and had luncheon, after which they were taken by specia motor buses to the plant of the Consolidated Shipbuildin Corporation where motor boats and engines of all sizes i various stages of construction were inspected. The membe of both Sections then attended the Motor Boat Show.

As a sequel to the paper presented by Lieut.-Com. H. Gil son, U. S. N., at the Motor Boat Meeting, the Pennsylvani Section will conduct a trip on the afternoon of Tuesday Jan. 18, to the League Island Navy Yard, where the bi German Diesel engine will be under observation. The part will leave the Engineers' Club at 3:30. Members of th Section will later dine at the Engineers' Club and hold discussion on Diesel engines. An excellent four-reel film o "The Story of Petroleum" will be shown. This film follow the liquid fuel from its source to the ultimate consumer.

OBITUARY

JULIUS A. PERKINS, mechanical director of the Universal Roller Bearing Co., New York City, died Dec. 7, 1920, at the age of 72 years. He was born at Hudson, Mich., in November, 1848. During his youth he worked about five years in a wagon shop at Sublett, Ill.; his further training for about 16 years was in his own machine shop and in various other shops in Omaha, Neb., Chicago, and Bremen and Berlin, Germany. His work included drafting, designing, making and superintending the manufacture of special machine and small tools and roller and ball bearings and parts. His engineering experience since the completion of his training included about 15 years inspecting manufacturing plants for fire insurance companies and in adjusting fire losses on manufacturing plants and machinery and over 16 years in designing, directing and superintending the drafting and making of special machinery and parts, and in the development of the Moffett and Perkins roller and ball bearings. He was a member of the American Society of Mechanical Engineers. He was elected to Member grade in the Society of Automotive Engineers, March 5, 1908.

WILLIAM T. R. PRICE, chief engineer of the oil engineering department of the Ingersoll-Rand Co., Phillipsburg, N. J., died at his home in Easton, Pa., Nov. 7, 1920, at the age of 35 years. He was born May 1, 1885, in Chester County, Pa., and, following his preliminary education, completed a three-year course in steam and machine design at Pratt Institute, Brooklyn, N. Y., in 1906. From 1908 to 1910, he lectured and gave instruction in general automobile construction, operation and repair, at the New York School for Automobile Engineers. Mr. Price was superintendent of motor transportation for the Government in the Philippine Islands from 1911 to 1913. He operated a motor transport system of 52 motor trucks over the difficult Benguet mountain road, for the Bureau of Public Works, and in 1913 supervised the transportation of 23,000 passengers and 7000 tons of freight without any loss of life or a serious accident. In the years 1914 and 1915 he was principal and part owner of the Toronto Automobile School, Toronto, Canad

His service for the United States Government from 191 to 1919 was distinctive. As sergeant, he had charge of a motor transportation at Madison Barracks, N. Y., and a second lieutenant rendered a similar service at Camp Mead Md. As captain and major, he was in command of the 304t Divisional Supply Train at Camp Meade and served for 1 months in France with the 79th Division. He was moto transport officer during part of the operations of this div sion and acting commander of trains during the severes American offensive in the Meuse-Argonne. As commande of the 304th Supply Train he was in charge of 500 men an 150 motor trucks. This supply train was eminently success ful in all of its operations. Major Price was cited for me itorious services in organizing motor transportation and fo expert technical and mechanical services in connection there with, by the commanding general of the American Exped tionary Force.

Following his Army service and until his demise, he wa engineer for the International Motor Co., New York City president of the Price Engine Corporation, New York City second vice-president of the Rathbun Engineering Co., Toledo Ohio, and chief engineer of the oil engineering departmen of the Ingersoll-Rand Co. He was elected to Member grad in the Society June 21, 1920.

BENJAMIN F. TOBIN, organizer and chairman of the boar of directors of the Continental Motors Corporation, Detroit died suddenly at his home in that city Nov. 23, 1920, at th age of 55 years. He was born at Chicago Nov. 29, 1865.

Mr. Tobin established the Continental Motors Corporatio and was connected with its activities in various capacitie during the past 16 years, being president and general man ager for several years prior to his death. He was mad chairman of the board of directors in January, 1920.

He was widely known in social and fraternal organization and was elected to Associate Member grade in the Societ Nov. 20, 1918.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Nov. 10 and Dec. 10, 1920. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ALCURE, FIRST-LIEUT. JOHN F. (J) chief inspector, Camp Holabird. *Baltimore.*

BAILLY, LOUIS (M) chief engineer, Ohio Municipal Equipment Co., *Columbus, Ohio,* (mail) 119 West First Avenue.

BARNES, NEWELL H. (A) cost accountant, Cushman Motor Works, *Lincoln, Neb.,* (mail) 1848 Prospect Street.

BATES, MORTIMER F. (M) assistant engineer, Sperry Gyroscope Co., *Brooklyn, N. Y.,* (mail) 1544 48th Street.

BENJAMIN B. R. (M) superintendent of experiments, McCormick Works, International Harvester Co., Chicago, (mail) 329 North East Avenue, *Oak Park, Ill.*

BESELIN, H. J. (M) production engineer, O. E. Szekely Co., Moline, Ill., (mail) 845 17th Street, *Rock Island, Ill.*

BIRD, D. A. (A) Cleveland Radiator Co., *Euclid, Ohio.*

BRADLEY, C. S. (A) district sales manager, Jones & Laughlin Steel Co., Pittsburgh, (mail) 1019 White Building, *Buffalo.*

BRAND, PAUL H. (M) chief engineer, Little Giant Co., Mankato, Minn., mail 608 Marion Street, *Oak Park, Ill.*

BREER, CARL (M) assistant chief engineer, Willys Corporation, *Elizabeth, N. J.*

BRENNER, RAYMOND E. (M) chief engineer, Coupler-Gear Freight-Wheel Co., *Grand Rapids, Mich.*

BRIGGS, JOHN W. (M) general superintendent, Cushman Motor Works, *Lincoln, Neb.*

BROWN, FRANK L. (M) general superintendent, White Motor Co., *Cleveland,* (mail) 1014 Lakeview Road.

BROWN, GEORGE M. (M) engineer, Liberty Devices Co., Boston, (mail) 853 Seventh Avenue, *New York City.*

BROWNTER, NELSON R. (J) draftsman, Bollstrom Motors, Inc., *St. Louis, Mich.*

BUDERUS, W. H. (M) automotive engineer, Sun Co., *Detroit,* (mail) 2476 Hazelwood Avenue.

BUTLER, E. J. (J) assistant engineer, Freeman Motor Co., Cleveland, (mail) 14315 Elm Avenue, *East Cleveland, Ohio.*

CARPENTER, MAJOR W. T. (S M) Coast Artillery Corps, care of Holt Mfg. Co., *Stockton, Cal.*

CASE L. B. (M) chemist, General Motors Corporation, *Detroit,* (mail) 2261 Garland Avenue.

CHRISMAN, CARL R. (J) draftsman, Garford Motor Truck Co., *Lima, Ohio,* (mail) 411 West Elm Street.

CLARK, HERBERT (M) Hotel Newton, High Street, *Worcester, Mass.*

COAPMAN, J. (M) chief engineer, Russel Motor Axle Co., *Detroit,* (mail) 2015 Highland Avenue.

COLLINS, F. ALTON, JR., (A) manager, Auburn Ball Bearing Co., 29 Elizabeth Street, *Rochester, N. Y.*

COMEY, H. C. (A) factory manager, Texas Motor Car Association, *Fort Worth, Tex.*

CREAMER, JOHN F. (A) manufacturers representative, Firestone Steel Products Co., *Akron, Ohio.*

CRONSTEDT, VALDEMAR NISON (J) draftsman, engineering department, Commercial Truck Co., *Philadelphia.*

CUMMINS, CLESSIE LYLE (A) president and general manager, Cummins Engine Co., *Columbus, Ind.*

CURRIE, ARCHIBALD P. (M) chief draftsman, Dominion Steel Products Co., Ltd., *Brantford, Ont., Canada* (mail) 236 St. Paul's Avenue.

DEIMEL, ALBERT H. (A) experimental engineer, Chrobeltic Tool Co., *Michigan City, Ind.*

DEMORE, L. A. (M) chief engineer, Mercury Mfg. Co., Chicago, (mail) 619 North Park Avenue, *Oak Park, Ill.*

DERR, H. E. (M) assistant chief engineer, International Harvester Co., Chicago, (mail) 113 East Center Street, *Akron, Ohio.*

DIESZ, EDWARD H. (M) assistant chief draftsman, International Harvester Co., *Akron, Ohio* (mail) 680 Edgewood Avenue.

DOLLIN, EDGAR N. (M) general manager, Precision Castings Co., Inc., *Syracuse, N. Y.*

DURLAND, HARRY S. (E S) student, Pratt Institute, Brooklyn, N. Y. (mail) 63 Hinsdale Place, *Newark, N. J.*

DYKSTRA, JAMES (J) designer, Saxon Motor Corporation, *Detroit,* (mail) 3408 Townsend Avenue.

FENTON, DANIEL H. (A) head of tire testing department, Fisk Rubber Co., *Chicopee Falls, Mass.*

FRAME, C. C. (M) chief transportation engineer, Service Motor Truck Co., *Wabash, Ind.* (mail) 447 North Thorn Street.

FRANCE, EDWARD A. (A) district sales manager, Jones & Laughlin Steel Co., Rockefeller Building, *Cleveland.*

FURUBAYSHI, USABURO (F M) chief inspector, automobile department, Tokyo Gas & Electric Engineering Co., Ltd., *Omori-machi, near Tokyo, Japan.*

GARGIULO, SALVATORE (A) master mechanic, G. & O. Mfg. Co., *New Haven, Conn.* (mail) 61 Lyon Street.

GILMAN, NORMAN H. (M) general manager and chief engineer, Allison Experimental Co., *Indianapolis* (mail) Box 894.

GRILL, C. H. (J) chief draftsman, Foote Bros. Gear & Machine Co., *Chicago.*

HALL, H. K. (A) general manager, Cleveland Radiator Co., Bliss Road, *Euclid, Ohio.*

HARRINGTON, C. G. (M) chief draftsman, Gardner Motor Co., St. Louis (mail) 7278 Anna Avenue, *Maplewood, Mo.*

HAWKINS, P. E. (M) engineer, Ohio Motor Vehicle Co., *Cleveland,* (mail) 18 Groveland Club, 14617 Lake Shore Boulevard.

HEGENAUER, CHARLES J. (J) mechanical draftsman, Chevrolet Motor Co., New York City, (mail) 25 Nepera Place, *Hastings, N. Y.*

HELMS, JOHN R. (A) director of instruction, Petz Automotive School, Inc., Philadelphia, (mail) 44 Morton Avenue, *Morton, Pa.*

HENDRICKS, R. G. (A) manager, King Motor Car Co., *Detroit,* (mail) 85 West Hancock Avenue.

HENRY, JOHN J. (A) engineer, Bethlehem Motors Corporation, *Pottstown, Pa.* (mail) Y. M. C. A.

HOERLE, NEWTON SWANK (M) manager of engineering department, Continental Motors Corporation, *Muskegon, Mich.*

JOHNSON, HOWARD M. (A) manager rebuilt truck department, Mack International Motor Truck Corporation, 1628 East Seventh Street, *Los Angeles, Cal.*

JOSEPH, LAWRENCE E. (M) sales engineer, Snead & Co. Iron Works, Jersey City, N. J., (mail) 11204 Willowmere Avenue, *Cleveland.*

KLEIN, FREDERICK H. (A) draftsman, Nelson Blower & Furnace Co., South Boston, (mail) 304 Amory Street, *Jamaica Plain (30) Boston.*

KLINE, CHARLES E. (A) superintendent assembly, Hahn Motor Truck & Wagon Co., *Hamburg, Pa.* (mail) Box 67.

KOEHNE, IRA CHASE (M) chief engineer, Preferred Motor Car Co., *Indianapolis.*

LANGENHEIM, ALBERT H. (M) chief draftsman, Eaton Axle Co., *Cleveland.*

LEAKE, THOMAS C. (M) engineer, Bear Tractor Corporation of America, Bridgeport, Conn., (mail) Herald Square Hotel, 114 West 34th Street, *New York City.*

LEMON, ARTHUR (M) engineer, Excelsior Motor Mfg. & Supply Co., 3700 Cortland Street, *Chicago.*

MCCLAIN, HARRY O. (M) chief engineer and production manager, American Truck & Trailer Corporation, *Kankakee, Ill.,* (mail) 788 South Osborn Avenue.

MCCREERY, H. L. (M) chief engineer, Standard Welding Co., *Cleveland.*

MCGRADY, ROY (E S) student, College City of New York, (mail) 147 Sixth Avenue, New York City.

MCKEE, WILLIAM J. (A) vice-president, Osgood Bradley Car Co., *Worcester, Mass.*

MARTIN, WILBUR A. (M) design engineer in charge of layout work, Glenn L. Martin Co., *Cleveland,* (mail) 1845 Belmore Road.

MERANDA, WILLIAM O. (J) chief draftsman, Hoosier Auto Parts Co., *Muncie, Ind.*

MILLER, J. MACKENZIE (J) test engineer, McCook Field, Dayton, Ohio, (mail) 4146 Floral Avenue, *Norwood, Ohio.*

MILLER, WILLIAM O. (J) draftsman, Holt Mfg. Co., *Stockton, Cal.,* (mail) 1009 North Sutter Street.

MOODY, COL. LUCIAN B. (S M) chief of tank, tractor and trailer division, Ordnance Department, *Washington.*

MOORE, FEARON D. (A) technical field representative, General Motors Export Co., *New York City* (mail) Box 86, Station G.

MORAND, LESTER J. (J) mechanical engineer, Morand Cushion Wheel Co., *Chicago.*

NEAL, FRANKLIN G. (A) patent attorney, Fisk Rubber Co., *Chicopee Falls, Mass.*

NEWELL, FLOYD BELL (M) mechanical engineer, Bureau of Standards, *Washington,* (mail) 417 Randolph Street.

O'NEAL, E. P. (J) instructor, Okmulgee Vocational High School, *Okmulgee, Okla.*

PERIN, DONALD W. (A) president, Perin Automotive Engineering Co., 10 Scotia Street, *Boston.*

POLHEMUS, DONALD W. (J) draftsman, Class Journal Co., New York City, (mail) Glen-Byron Avenue, *Nyack, N. Y.*

PURVIS, JOHN W. (A) designing engineer, McCord Mfg. Co., *Detroit,* (mail) 280 West Ferry Avenue.

RAPIN, EDWARD A. (J) layout draftsman, Oakland Motor Car Co., Pontiac, Mich., (mail) 1129 North Webster Street, *Saginaw, Mich.*

REED, RODMAN S. (M) chief engineer, Brockway Motor Truck Co., *Cortland, N. Y.,* (mail) 33 West Court Street.

RODGER, DAVID WILLIAM (A) sales manager, Muzzy-Lyon Co., *Detroit.*

SAWYER, WILFRED D. (J) assistant engineer, Baker Steam Motor Car & Mfg. Co., *Pueblo, Col.,* (mail) 110 West 12th Street.

SCHLACHTER, DEAN H. (A) supervisor of motor mechanics school, Fort Crook, Neb., (mail) 2333 South 35th Avenue, *Omaha, Neb.*

SCHREIBER, KARL O. (A) assistant superintendent, International Harvester Co., *Springfield, Ohio.*

SCHULER, C. R. (M) engineer, truck and tractor division, Midwest Engine Co., *Indianapolis*, (mail) Haugh Hotel, 11 East Michigan Street.

SCHULTZ, J. A., JR. (A) assistant manager, Doehler Die-Casting Co., *Toledo, Ohio*, (mail) 1422 Goodale Avenue.

SEAVERNS, BYRON H. (M) designer, Service Motor Truck Co., *Wabash, Ind.*

SOHN, MILTON G. (J) mechanical draftsman, Holt Mfg. Co., Stockton, Cal., (mail) General Delivery, *Pittsburg, Cal.*

STERN, MARCUS (M) chief engineer, Doehler Die-Casting Co., *Toledo, Ohio*, (mail) 2342 Rosewood Avenue.

STOCKFLETH, BERGER (M) chief engineer, International Harvester Co., *Chicago*, (mail) 2422 Drake Avenue.

STONE, FRANK J. (A) branch manager, Electric Storage Battery Co., 718 Beacon Street, *Boston.*

STUDNICKA, JOSEPH (M) tool and machine designer, Dodge Bros., *Detroit*, (mail) 4454 Moore Place.

TAYLOR, EDWARD CURTIS (M) patent attorney, Fisk Rubber Co., *Chicopee Falls, Mass.*

TORRANCE, JAMES B. (M) assistant professor, University of Minnesota, St. Paul, Minn., (mail) 3744 Portland Avenue, *Minneapolis, Minn.*

WALLACE, WILLIAM M. (M) chief draftsman, bureau of construction and repair, Navy Department, *Washington.*

WALTER, C. G. (A) service manager, Standard Steel Car Co., and secretary, Pittsburgh Model Engine Co., *Pittsburgh*, (mail) Standard Steel Car Co.

WALTERS, R. F. (A) branch manager, Carr Fastener Co., *Detroit*, (mail) 190 Moss Avenue.

WARE BROS. Co. (Aff) 1010 Arch Street, *Philadelphia.* Representatives: Albert P. Cardwell, editor *Vehicle Monthly.*

WEINBERG, FRED (M) consulting engineer, General Motors Corporation, New York City, (mail) 42 Watson Street, *Detroit.*

WINKLESS, P. E. (J) mechanical engineer, Acme Steel Goods Co., *Chicago*, (mail) 7350 Drexel Avenue.

WISENBURGH, C. B. (A) Western sales manager, Standard Steel & Bearings, Inc., Philadelphia, (mail) 1511 Kresge Building, *Detroit.*

YERAM, ZAKAR A. (M) chief draftsman, general supply department, *Fairfield, Ohio*, (mail) engineer office, Aviation General Supply Depot.

Applicants *for* Membership

The applications for membership received between Nov. 24 and Dec. 22, 1920, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

AHLENE, C. M., sales and service engineer, Borg & Beck Co., *Moline, Ill.*

APOR, EMIL L., experimental work, Fairbanks-Morse & Co., *Beloit, Wis.*

BACON, CHESTER A., chief engineer, Auburn Division, Bowen Products Corporation, *Auburn, N. Y.*

BAKER, HAMMOND D., district sales manager, Roller-Smith Co., *Bethlehem, Pa.*

BARTLETT, LEROY A., factory representative, Detroit Steel Products Co., *Detroit.*

BARTON, LOY E., student, University of Arkansas, *Fayetteville, Ark.*

BEVERIDGE, FIRST-LIEUT. JOHN, JR., chief of engines branch, property division, Air Service, *Washington.*

BLAKE, E. A., in charge of experimental department, Transport Truck Co., *Mount Pleasant, Mich.*

BONELL, RALPH K., engineer, C. H. Wills & Co., *Marysville, Mich.*

CARPENTER, FIRST-LIEUT. CHARLES L., Quartermaster Corps, *Camp Dodge, Iowa.*

CASTRICONE, JOHN A., superintendent, Pittsburgh Model Engine Co., *Pittsburgh.*

CRAMER, V. C., F. S. Carr Co., 31 Beach Street, *Boston.*

CURRIE, CARLETON H., assistant in mechanical engineering department, Michigan Agricultural College, *East Lansing, Mich.*

DIFFENBAUGH, CAPT. HARRY, Quartermaster Corps, *Camp Devens, Mass.*

DONAHUE, FRANK W., treasurer, F. W. Donahue Co., Inc., *New York City.*

FIRST, HARRY V., designing engineer, Root & Van Dervoort Engineering Co., *East Moline, Ill.*

FOSKETT, MAYNARD L., chief engineer, Charleston Steam Tractor & Truck Mfg. Co., *Dunbar, W. Va.*

FULDA, RENE, civil engineer and director, Societe Francaise des Automobiles White, *Paris, France.*

GAGE, OSCAR THOMAS, assistant general foreman, Sheridan Motor Co., *Muncie, Ind.*

GEIGER, JOHN W., research assistant and instructor, Purdue University, *Lafayette, Ind.*

GIFFORD, ALBERT J., partner, Leland-Gifford Co., *Worcester, Mass.*

GOTTSCHAU, C. M., mechanical engineer, Great Western Sugar Co., *Denver.*

GRUNDY, GEORGE H., general sales manager, Poldi Steel Corporation of America, *New York City.*

HACH, EDWARD C., designer, Saxon Motor Car Corporation, *Detroit.*

HART H. P., chief engineer, Bollstrom Motors, Inc., *St. Louis, Mich.*

HUNT, WILLIAM H., JR., automotive engineer, First Heavy Mobile Shop, *Camp Meade, Md.*

INFIORATI, M. E., JR., chief engineer and assistant general manager, J. M. Lapointe Co., *New London, Conn.*

KAESS, CHARLES A., general manager, Automobile Crank Shaft Corporation, *Detroit.*

KEMP, JOHN M., buyer, Hinkley Motors Corporation, *Detroit.*

KOETZLA, DAVID J., automobile race driver, Stratford Hotel, *Chicago.*

KULP, A. DENNISON, automotive engineer, Standard Oil Co. of California, *San Francisco.*

LAZARNICK, NATHAN, proprietor, Commercial Photography, 246 West 42nd Street, *New York City.*

LEVENE, BENJAMIN, Levene Motor Co., *Philadelphia.*

MOUGET, MARCEL G., mechanical engineer, Midwest Engine Co., *Indianapolis.*

MUELLER, FRANK G., chief engineer, Maccar Truck Co., *Scranton, Pa.*

MULLER, MICHAEL, sales engineer, Vacuum Oil Co., *Chicago.*

MURRAY, W. T., electrical work and storage batteries, I. J. Cooper Rubber Co., *Nashville, Tenn.*

NORELIUS, EMIL F., consulting engineer, *Minneapolis.*

PANNELL, ERNEST V., engineer, British Aluminum Co., Ltd., *London, England.*

PATRICK, FRANK E., sales representative, Cuno Engineering Corporation, *Meriden, Conn.*

PATTEN, RAYMOND E., body engineer and chief draftsman, Colonial Motors Corporation, *Boston.*

PITTMAN, KNOWLES, sales manager, Electric Steel Co., *Chicago.*

PRENTICE, WILLIAM G., gage supervisor, Eaton Axle Co., *Cleveland.*

PRINKEY, JOHN WARD, mechanical engineer, Dayton Engineering Laboratories Co., *Dayton, Ohio.*

ROESCH, H. A., chief inspector, Moline Engine Co., *East Moline, Ill.*

SELLSTROM, ELMER W., assistant general manager, Dahlstrom Metallic Door Co., *Jamestown, N. Y.*

SHAKESPEARE, MONROE, engineer, Shakespeare Co., *Kalamazoo, Mich.*

SMITH, GEORGE AUSTIN, automotive sales department, Electric Storage Battery Co., *New York City.*

SPEICHERT, OTTO C., assistant superintendent, Pittsburgh Model Engine Co., *Pittsburgh.*

STEADMAN, CLAUDE A., chassis and motor layout, C. H. Wills & Co., *Marysville, Mich.*

TAWRESEY, JOHN S., assistant to chief engineer, Standard Steel & Bearings, Inc., *Philadelphia.*

TEER, DONALD M., vice-president and general manager, Vulcan Engineering Co., *Jackson, Mich.*

THOMPSON, J. K., president and general manager, Auto Engineering Co., *Detroit.*

TORRESEN, CAREL THEODORE, chief draftsman, tank, trailer and tractor division, Ordnance Department, *Cleveland.*

VAN SANDWYK, MARINUS C., automobile mechanic, Sweeney Auto School, *Kansas City, Mo.*

VICKERS, HARRY F., engineer, Arthur L. Eaton, *Los Angeles, Cal.*

WALLACE, GEORGE B., technical head of tractors division, General Motors Export Co., *New York City.*

WEST, MYERS BURTON, salesman, Goodyear Tire & Rubber Co. of California, *San Francisco.*

WHITING, LIEUT. EDMUND ALDEN, bureau of construction and repair, Navy Department, *Washington.*

WILLIAMS, CHESTER P., sales engineer, Northway Motors Sales Co., *Boston.*

WREAKS, HUGH T., Detroit manager, Boston Insulated Wire & Cable Co., *Detroit.*

YEAGER, HENRY M., factory manager, Fedders Mfg. Co., Inc., *Buffalo.*

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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The Annual Meeting

IT is hard to appreciate fully the part automotive vehicles have in our national life, not to mention the development that is to come in passenger cars; motor trucks; farm, military and industrial tractors; motor boats; aircraft; semi-portable engines; and farm lighting units. It is clear that the form and extent of use of these are in their infancy. One's mind can grasp only in a general way what will be the manner and effect of the economical design, production, use and servicing of tens of millions of these vehicles. The intellect of a Jules Verne or an H. G. Wells is not adequate for the visualization of what the automotives will be and do.

In the effort to restore that proper economic balance which is essential to national prosperity the automotive engineers will play their full part. That was fully demonstrated at the sessions of the Society held in New York City last month at which the attendance was over 30 per cent larger than it was at the corresponding sessions last year.

It is said that the American farmer produces four times as much food per human unit as the European; he replaces three men by using horse or power-driven machines and decreases the cost materially. Were it not for plows, harrows, rollers, cultivators, seeding machines, trucks, tractors, hay-making tools, harvesters, threshers, gas engines, diggers, dairy machines and appliances and hundreds of other tools and machines, the production of our farms would be one-fourth what it is. The work of the members of the Society is very largely concerned with motorization and the application of machinery of which the internal-combustion engine is the heart, to the fundamental operations of production and distribution of the staple articles of commerce.

The automotive engineer is preparing for the greater and greater intensification of machine and traffic methods that will inevitably come in this country, and for world-wide trade on which all our operations are so widely based. In this he is not forgetting sane requirements in the demand for the various types of automotive apparatus, or the vital necessity of the maintenance of standardization that will make possible that interchangeability of many materials, parts and accessories that is economically requisite. Many of the benefits of civilization are furthered by the activities of the Society.

At the dinner, George E. Roberts pointed out that if anyone knows what is the matter with the world at the present time, it is the engineer. With the division of labor in industrial development, the engineer devised ways and means to increase productive power as a whole. The loss of the world equilibrium, the equilibrium in world trade, has cost us a state of equilibrium in this country, notwithstanding the fact that owing to our resources being so varied and so great we are more nearly independent of the rest of the world than any other country. Mr. Roberts' theme was that there cannot be a state of general prosperity in either international trade or domestic affairs without an equilibrium in industry; that there cannot be a full distribution of products or full employment unless industry is in balance, all business in the last analysis being simply an exchange of products. The town industries and the great farming industry, together with the people immediately dependent upon it, must be brought into a comparative state of balance. All of the wage earners in an industry together do not have in their power the fixing of the amount of the wages that will be paid in the industry, because the amount of wages that will be paid depends upon the amount of goods that can be sold, and in turn the amount of goods that can be sold depends upon the ability of the public to buy. The engineer has shown the whole world how industry can be revolutionized by highly organized production. The engineers have done more than any other group of men to teach the lesson that the essential thing about wages is not the wage rate per week or per day but the cost of labor per unit of product. That is the golden key to the solution of the entire industrial problem. The people of this country must understand that they are vitally concerned in large-scale increasing production. There is no limit to the benefits that can be derived in this respect.

In connection with the expansion and restriction of credits, Mr. Roberts said that it is an established fact that people in general never use the earnings of good times to pay their debts but use them as a basis for further borrowing. People make their debts in good times and pay them under pressure in hard times. The condition of this country is remarkably good considering the experience through which we have passed and the readjustments that were absolutely necessary. In other similar situations in our history the reaction in business has come from a period of expansion during which there was a great amount of development and construction. We have had a period of expansion due to our expenditures in war, this being stimulated by war business. The country is much underbuilt today. There is a great backed-up demand for development and construction work which will be done speedily provided the general conditions in industry are favorable. There are millions of automobiles which ought to be built, and airplanes should be produced, as well as enormous amount of other automo-

tive apparatus; and they will be built as soon as the industries of the country are brought back into balance.

Toastmaster Kettering expressed the view that the members had never attended a banquet at which they received more real substantial information, this dinner giving a new perspective of our whole business situation. He said that the engineers understand what the sales department wants: something they can sell; that last year the sales departments blamed the designing and producing engineers because automotive apparatus was not turned out fast enough, and say now that the trouble is that it is not good enough.

Vice-President Cowie, of the American Railway Express Co., argued that there is no reason why the United States Government should not give as much support to commercial aviation as it does to water navigation, and that it is absolutely imperative that models of commercial airplanes which can be readily altered to become effective weapons of war should be developed. He said that the great work that the automotive industry did during the war was possible because that industry was fundamentally sound and operating on a proper basis, the manufacturing of vehicles being so standardized as to make their rapid conversion practical. Although America is the home of the airplane, nothing important seems to have been done by the Government to conserve our valuable aeronautical assets. Mr. Cowie emphasized the great necessity for immediate encouragement of commercial aviation.

In connection with transportation in general, Mr. Cowie pointed out that the problem is one of coordinating a great number of different types of mediums ranging from wheelbarrels to airplanes, and including trucks, single-horse and double-team outfits, automobile trailers, double-end electric platform trucks, automobiles, gasoline engines, tractors, electric trucks and experimental airplanes and dirigibles. He urged the need of simplifying motor vehicles; stripping the chassis until nothing is left but those things that are essential for efficiency. He believes that such procedure will reduce costs in production and operation and increase sales greatly. Mr. Cowie is a great believer in future aviation, saying that in this country of vast distances and unexplored resources transportation is a paramount matter, the cost of it determining largely selling price. This phase of his argument makes clear the great and far-reaching opportunity before the automotive engineer.

David Beecroft, president-elect, in discussing the major activities of the Society, referred to its including in its circle of membership eight distinct but closely related industries, all centered about the use of the internal-combustion engine. Inasmuch as the apparatus produced by the members goes into the hands of the average citizen of all the countries of the world, it is vitally necessary to carry rationally to the user a message explaining how the apparatus should be used. He said that the apparatus has by no means reached the status of perfection. In the motor car, the oldest and largest member of the automotive circle, many problems are to be solved. He referred to the great influence the internal-combustion engine has had in bringing the rural population up to the level of urban conveniences and comforts. We have the great world field before us. With factory capacity expanded greatly during the war, we must give attention to the needs of the rest of the world. The motor vehicle is an international piece of mechanism in all its forms and the members must look beyond the confines of their own country and scan the conditions under which the vehicles they produce must operate in many different countries. Local conditions must be recognized, the goal in mind being service to not only this country but all the countries of the world, the automotive apparatus being as easy of application, operation and maintenance as possible.

Aeronautical Engineering Session

The aeronautical engineering session, directed by Glenn L. Martin, aroused considerable interest and was attended by 210 members and guests. The paper on Airplane Propellers by F. W. Caldwell, read by L. E. Pierce in the absence of the author, outlined the progress made in propeller design and construction during the past year. Mr. Caldwell described the various blade forms most generally used and told of the perfection of a method of molding propellers from a composition under great pressure. Testing methods for studying propeller performance have been improved and it is now possible to record torque and thrust readings under actual flying conditions. The advantages of reversible-blade propellers were referred to by the author, tests conducted by the Government which had demonstrated the practical value of one experimental propeller of this type being mentioned. Grover C. Loening read a paper on the Design Requirements of Commercial Aviation. Single and multiple-engined types of commercial airplane were compared, the author drawing conclusions which favored designs providing for the installation of only one engine. Mr. Loening recommended the use of all-metal and wood-and-metal construction in combination, believing that each has a place in certain parts of the airplane structure.

C. D. Hanscom in his paper on Airplane Wings, described some recent wind-tunnel tests of new wing sections and presented curves indicating the characteristics of these sections which showed that unusual efficiencies had been attained. He also outlined the results of tests which gave an idea of the effect of adjustable front and rear wing flaps on lift and drift, demonstrating the benefits resulting from the use of variable-camber wings. Major Thurman H. Bane was unable to present his paper on the Progress of Military Aviation but was ably represented by Major H. S. Martin, who gave a very interesting description of the recent work done at McCook Field. Pictures were shown of experimental aviation engines of unusual types, the latest models of war planes and the new airplane cannon developed by the Ordnance Department. The motion pictures of parachute jumps were very entertaining and impressed the members with the practicability of the parachute as a life-saving device.

Annual Business Meeting

President J. G. Vincent was in the chair at the annual business meeting held during the morning of Jan. 12. After expressing his appreciation of the splendid support and cooperation accorded him during the past year by the officers and members of the Society, he gave a comprehensive survey of the Society's activities during this period.

In reference to membership, it was brought out that there is a net gain of 715 members for the year as compared with 651 for the previous year. The activities of the various Sections were considered as having been highly commendable and the belief was expressed that the Sections are experiencing healthy growth. The work of the administrative committees was pronounced most satisfactory as to both volume and quality, under condi-

tions that had made this work more than usually burdensome.

Passing then to the work of the Standards Committee, President Vincent summarized its comprehensive activities, stating that in one sense the real value of standardization is just beginning to be realized, and suggested that doubtless much more can be done by way of simplifying, facilitating and improving the manufacture of the products with which the automotive industry is concerned and the economical use of which in service must be fostered. He then enumerated the many present cooperative activities of the Society with the work of other societies and organizations in allied fields, inclusive of active cooperation with various bureaus and departments of the Government, placing emphasis upon the solution of the fuel problem. It was suggested, however, that there is a limit dictated by common sense to the scope of coordinated activities that can be beneficial jointly or severally and that, with regard to both the domestic and foreign affairs of the Society, this should operate to protect it from too great complexity of effort. In this connection and also concerning the relation of the Society to the Federated American Engineering Societies, it was stated that a properly conservative policy indicates the assumption of a continuance of the Society's previous attitude of close attention to automotive matters in practically the same degree as heretofore.

The efficiency of the organization and the work of the Council and the office staff of the Society were commended and comparisons in regard to the Society's remarkable growth were made, inclusive of financial and publication statistics. Since the time that Coker F. Clarkson became Secretary and General Manager of the Society 10 years ago, at which time the office equipment consisted of desk space in an office, there were less than 400 members and Mr. Clarkson was the sole employe, the office staff has increased to 50 persons, the office space required is 7500 sq. ft. and there are over 5000 members of the Society resident throughout the world.

President Vincent then discussed the future activities of the Society at considerable length and indicated desirable procedure along the lines of standardization, both national and international, foreign relations, the work of the proposed Research Committee recently authorized, committee and Sections' work in general and the work on internal-combustion engine fuel. The future problems of the automotive industry were enumerated and commented upon by him in considerable detail, these being inclusive of the successful quashing of the present general idea that the passenger automobile is to a large extent a luxury, the prevention of possible greatly increased taxes on automobiles and trucks, the need for a Federal licensing system because of the increasing amount of interstate commerce by motor truck and the removal of the three handicaps—road construction, fuel and cost—which must be accomplished before the automobile can render its full service to this country. The obstacles to the removal of these handicaps upon the industry were specified and an outline of much practical value for overcoming them was given.

The final portion of President Vincent's address was devoted to a summary of aircraft development and a discussion of its possibilities. It is evident that there has been a steady improvement in the reliability of the airplane, an extension in the use of aircraft where this was justified by the inherent advantages of this system of transportation and attainment in the field of research limited alone by the funds available. President Vincent stated further that perhaps the most conspicuous tendency in airplane engine design is to pay more attention to efficient operation at altitude and under reduced throttle conditions obtaining during average flights. This involves in some cases special precautions against running wide-open near the ground, except for short periods with the aid of special fuels to guard against preignition and detonation. In this manner it is possible to effect considerable savings in fuel consumption at altitude, together with an increase of available power under normal flying conditions.

The following resolution relative to the status of the proceedings at the 1920 Summer Meeting at Ottawa Beach, Mich., was then presented by T. C. Menges and was adopted.

Resolved, that all acts of the Society done by it at its meetings held in Ottawa Beach, Mich., June 21 to 25, 1920, and all resolutions adopted by it at these meetings, be and the same hereby are in all respects confirmed, approved, ratified and adopted, as the acts and resolutions of this Society with the same effect as if they had been adopted by this Society at a meeting held in the State of New York; and be it further

Resolved, that any and all the acts of any of the officers of the Society done under any of the said resolutions be and the same are hereby confirmed and ratified.

Financial and Membership Reports

The report of Treasurer C. B. Whittelsey for the fiscal year ended Sept. 30, 1920, showed the total assets of the Society to have been $151,627.39. The total liabilities were $21,977.31, making the unexpended balance in the treasury $129,650.08 at the end of this period. The income for the year, including initiation fees, dues, publication, advertising and miscellaneous sales, and contributions and interest, amounted to $247,206.55. The operating cost for the year was $227,650.43, which leaves $19,556.12 as the unexpended income for the last fiscal year and is a commendable result.

The report on the membership of the Society was to the effect that the average number of applications received per month during the past seven months was approximately 90 as compared with an average of approximately 77 per month during the same period of 1919. The total number on the rolls of the Society on Jan. 1, 1921, including Affiliate Member Representatives and Enrolled Students, was 5231, constituting a net gain of 465 since June 1, 1920, after 108 had ceased to be members owing to resignation or non-payment of dues. This is a net gain of 715 members for the year, as compared with 651 for the previous year.

The increase of membership since December, 1909, is shown in Table 1.

TABLE 1—INCREASE IN MEMBERSHIP

Year ended Dec. 31	Total Members	Percentage Increase
1909	393	....
1910	654	66.4
1911	982	50.1
1912	1,447	47.3
1913	1,713	18.4
1914	1,743	1.8
1915	1,783	2.3
1916	2,121	19.0
1917	3,284	54.8
1918	3,986	21.4
1919	4,516	13.3
1920	5,231	15.8

In Table 2 the membership is analyzed by grades.

TABLE 2—MEMBERSHIP ANALYZED BY GRADES

Grade	1919	Percentage of Total	1920	Percentage of Total
Members	2,360	52.3	2,706	51.7
Service Members	13[1]	0.3	18[1]	0.3
Foreign Members	11[1]	0.2	50[1]	1.0
Associates	1,350	29.9	1,495	28.6
Juniors	514	11.4	692	13.2
Affiliate Members	95	2.1	112	2.1
Affiliate Member Representatives	110	2.4	117	2.3
Enrolled Students	63	1.4	41	0.8
Total	4,516	100.0	5,231	100.0

[1]These figures do not include all the members resident abroad or employed by the United States Government.

Table 3 shows comparative figures regarding the number of applications for membership during 1918, 1919 and 1920.

TABLE 3—APPLICATIONS FOR MEMBERSHIP RECEIVED

Month	Year 1918	Year 1919	Year 1920
January	65	74	69
February	49	82	93
March	45	83	101
April	56	100	166
May	126	78	173
June	107	69	103
July	71	54	76
August	88	23	104
September	76	71	82
October	59	107	70
November	122	111	113
December	102	100	73
Total	966	952	1,223

Report of the Council

The substance of the report of the Council is embodied in the Treasurer's Report, the report of the Membership Committee and the list of members elected during the past year. In addition, Mr. Clarkson touched briefly on a few other specific and general matters.

Table 4 shows the large amount of publication work accomplished during the last fiscal year.

TABLE 4—VOLUME OF PUBLICATIONS FOR THE FISCAL YEAR ENDED SEPT. 30, 1920

Publication	Number of Copies	Pages per Copy	Total Number of Pages
THE JOURNAL	74,000	200	14,800,000
TRANSACTIONS Part II—1918	4,500	500	2,250,000
TRANSACTIONS Part I—1919	4,300	810	3,484,000
Data Sheets	592,000 leaves ..		1,184,000
Membership Roster	10,000	325	3,250,000
			24,968,000

In the Statistical and Addressing Department of the Society the members' list or roster is kept in card form, alphabetically, by company, geographically and by position held. This one file contains over 20,000 cards, each card being cross-referenced five times for easy accessibility of information. During the past year there were 5800 additions and changes in the above-mentioned cards. This means that 58,000 individual cards were changed during the year, besides other records and reports of the changes sent to the Sections and other departments. All mail returned from the Post Office for better address is referred to this department and the sendee is systematically followed up until found and the address corrected. The envelopes for all general notices being mailed to the membership, the wrappers for the mailing of THE JOURNAL and labels for the mailing of sundry publications, are all addressed by machinery in this department.

Mr. Clarkson then presented the following interesting analysis of costs, the figures being based on the total operations, including meetings, of the last fiscal year.

(1) The unexpended income was 7 per cent of the turnover
(2) The salaries amounted to 34 per cent of the turnover
(3) The expense for drawing, engraving, printing and binding amounted to 26 per cent
(4) The meetings expense, including the cost of hotel accommodations, dinners and meeting rooms, was 13 per cent
(5) Rent and improvements were 4 per cent; postage, shipping, telephone and telegraph expenses, 4 per cent; stationery and supplies, 2 per cent; traveling expenses, 2 per cent; and miscellaneous expenses, 8 per cent.

The average cost per member for the last fiscal year is stated in Table 5.

TABLE 5—AVERAGE COST PER MEMBER

Activities	Cost per Member
Publications	$15.67
Standards	4.33
Meetings	12.74
Membership Increase	1.50
Sections	1.90
Rent and Improvements	3.26
General Administration	18.44
Cost of Sales	0.83
Total	$58.67

The expense of the Standards Department during the 1919-1920 fiscal year was slightly over $31,000, including general administration overhead. The corresponding figure for the Sections Department was $13,800. The cost per member of meetings of the Society held last year is given in Table 6. After adding general administration overhead and deducting the income from the meetings mentioned in Table 6, the net expense per member for all of the meetings was $10.65. The cost of the Accounting Department for the fiscal year was $6,426.09, and that of the Stenographic Department $10,475.39.

TABLE 6—COST OF SOCIETY MEETINGS PER MEMBER

Meeting	Cost per Member
Aeronautic	$0.33
Chicago	1.24
Kansas City	0.34
Motor Boat	0.07
Winter, annual	4.12
Summer, semi-annual	5.62
Meetings Department and Sundries	1.02
	$12.74

The direct cost of holding Council meetings during the period in question was $514.21. The postage bill of the Society for the fiscal year was $7,350.64. The telegraph and telephone expense was $2,154.87 and the traveling expense of all departments was $6,651.09. These are typical items of the operations of the Society.

Regarding the present status and growth of the auto-

motive industry, as indicating the volume and complexity of the future work of the Society, Mr. Clarkson went on to say that if one glances back to the time of William Shakespeare, the greatest of British poets, one will recall that in 1586 he made his way to London in search of work and opportunity. London at that time had 150,000 inhabitants. In those days there were two well established routes from Stratford-on-Avon to London. The roads were few, bad and dangerous. Journeys were made in the saddle or on foot; there were no other methods of travel. Goods of all kinds were carried by pack-horses; wagons were very crude and very rare. It should be borne in mind that vehicles were not run as public conveyances until the seventeenth century was well under way.

Today, at least 8,500,000 automobiles, passenger cars and motor trucks, are in greater or less use in the United States. There are, in addition, nearly 400,000 farm tractors; more than 1,000,000 stationary engines of the internal-combustion engine type; and probably over 200,000 motor boats. These machines, approximately 10,000,000 in number, consume a large percentage of the 100,000,000 bbl., more or less, of gasoline produced annually, and a large amount of kerosene.

In 1923 there will be in use, allowing for machines discarded after five or six years of service, probably more than 9,000,000 passenger cars; close to 2,000,000 motor trucks; upward of 1,000,000 farm tractors; and more than 1,500,000 stationary engines. This means, without counting aircraft, over 13,000,000 machines of the various types mentioned, if the economic and financial balance hoped for is restored soon.

As we reach and advance from this stage we shall need another Shakespeare to visualize and guide our activities. In any event our work is cut out for us on a very large scale. The Council bespeaks accordingly the best effort and aid of all the members of the Society in conformity with its established precedents and in continuance of the remarkable loyalty and the generosity of the members that have made the achievements of the Society possible.

Report of the Standards Committee

The Standards Committee reported for approval at the meeting 34 recommendations; 13 were on new subjects, 17 involved revision and extension, 3 were cancellations of previously accepted recommendations and 1 was a special report. In January and June, 1920, there were reported 48 and 49 recommendations respectively, by 14 Divisions. The number of Standards and Recommended Practices contained in the new edition of Vol. 1 of the S. A. E. Handbook, recently issued in rearranged form, is 210. The Committee has now in hand in various stages of progress more than 200 subjects. The specific action taken with regard to standard recommendations at the Standards Committee meeting held Jan. 11, 1921, is reported in full in this issue of The Journal.

Sections and Meetings Committee Reports

Thirty meetings have been held during the past year by the 10 Sections of the Society, the subjects discussed having been related not only to engineering problems but to the economic trends of today. The Section established in Boston and the Section continued at Washington after the war period have been successful from the start.

The Meetings Committee report enumerated the important general meetings of the Society held during its 1920 administrative year and stated that there had been a total attendance at these meetings of approximately 2500 and an attendance at dinners held by the Society of about 2800.

During the summer and autumn of 1920 the Society participated in meetings of the National Gas Engine Association at Chicago, and of the American Petroleum Institute at Washington. During the year, 93 papers were presented, classified as follows: Aeronautics, 14; bodies, 6; fuel, 28; motor boat, 8; passenger car, 8; farm tractors, 6; transportation and highways, 10; motor trucks, 6; and general topics, 7.

Election of Officers

T. S. Campbell, Glenn Muffly and C. E. Heywood were appointed as tellers of election of officers to serve during this administrative year and of Councilors to serve during 1921 and 1922.

They reported that 917 valid and 14 invalid ballots had been cast, 884 of the valid ballots having been according to the nomination and 36 miscellaneous. The total count on election is as follows:

For President
(To serve for one year)

	For	Against
David Beecroft	910	7
H. W. Alden	1	
W. P. Chrysler	1	
H. L. Horning	1	

For First Vice-President
(To serve for one year)

H. L. Horning	911	6
A. W. Scarratt	1	
David Beecroft	1	

For Second Vice-President Representing Motor Car Engineering
(To serve for one year)

B. B. Bachman	910	7
H. L. Elfes	1	
A. T. Sturt	1	

For Second Vice-President Representing Aviation Engineering
(To serve for one year)

H. M. Crane	912	5

For Second Vice-President Representing Tractor Engineering
(To serve for one year)

E. A. Johnston	904	13
D. P. Davies	1	
A. W. Scarratt	1	

For Second Vice-President Representing Marine Engineering
(To serve for one year)

Joseph Van Blerck	910	7

For Second Vice-President Representing Internal-Combustion Stationary Engineering
(To serve for one year)

T. C. Menges	911	6

For Councilors
(To serve for two years)

W. A. Brush	905	12
F. W. Davis	914	3
H. A. Coffin	1	
Allen Loomis	1	
Horace Smith	1	

For Treasurer
(To serve for one year)

C. B. Whittelsey	915	2

Those receiving the largely preponderating numbers of votes were the nominees of the regular Nominating Committee, no other nominations having been made, and were declared elected. There are 15 voting members of

the Council. Ten have been newly elected as stated above. The others are Past-President Vincent and Councilors F. M. Germane, N. B. Pope, A. W. Scarratt and Glenn L. Martin. The first four are holding over in accordance with the provisions of the Constitution and Mr. Martin was chosen by the Council to fill a vacancy which existed.

Remarks of President-Elect Beecroft

As soon as the report of the tellers was accepted President-Elect Beecroft was escorted to the platform and made a few remarks. He said in part:

> The volume of work and the importance of the Society as we have seen them develop under the very able leadership of Colonel Vincent during the past year, impress me with the seriousness of the responsibilities that rest upon the President of this Society.
>
> I pledge you the very best that I can give during the coming year, and that will be very largely the result of the excellent Council that has been elected this morning. It will be a great pride and one of the highest honors in my life to have the opportunity of giving aid in guiding the activities of the Society of Automotive Engineers during the year 1921.
>
> My familiarity with the activities of the Society in the last four or five years, during which time I have been connected with the Meetings Committee, has given me an opportunity of looking into the possibilities of the Society; and what Colonel Alden, Mr. Crane, Mr. Moskovics and Colonel Vincent have said this morning regarding the responsibilities of the engineer, makes me feel the load all the more.
>
> We are approaching new problems each year in our industry. Some years ago the sole problem, let us say, was that of design. Then we approached the greater problem, five years ago, of production. To those problems we have added today that of maintenance, because we must not forget that we have 9,000,000 motor vehicles in the different countries of the world, and that it is just as essential that they be kept at a standard of efficient operation and scientific application as it is that we go on building more. I feel that the Society must give more attention to that aspect of the work; and I would like to subscribe in a general way to what Colonel Alden and Mr. Crane said as to the necessity of the engineer having a wider vision, a world view, of our industry and his part in it.
>
> I wish to thank you very sincerely for the unexpected honor of being elected President of the Society, and I again pledge you that all that I can do in 1921 for the pushing forward, uplift and constructive advancement of the Society will be done.

Addresses

Following the regular business session, President Vincent called upon H. M. Crane, Col. H. W. Alden, F. E. Moskovics and J. G. Utz to express their views regarding The Engineer's Place in the Industry.

Remarking upon the comparatively recent origin of engineering as a profession, Mr. Crane stated that the line which has unconsciously been drawn between scientists, as such, and the scientific men, or engineers, who make science practical and its products available to all, has been a cause of friction and retarded the progress of the engineer in reaching a position where the engineering department is considered of equal importance with the departments of production and selling. The former close connection between designing and building has become more or less broken as the manufacturing plants have increased in size and the men in the different departments are often too widely separated. The extreme of specialization has been reached and in some respects its result is inferior to that obtained under former conditions but, as no one man can acquire all the necessary knowledge, it is possible to approach the efficiency of the former methods by taking a broader view of the engineer and engineering and by cooperative effort. The engineer is expected to know foundation principles and the capacity for accuracy for all operations. He should use this knowledge in his original designs and not depend upon the shop for such matters. In this the shop representatives should meet the engineer half-way. The difference between the best and worst factory managers is simply one of viewpoint. It is within the province of the engineer to consider the salability of the product. The engineer is the best judge of what the public should have, because he knows what can be done. The sales viewpoint is for today, but the viewpoint of the engineer should be for at least two years into the future. The engineer must know the past, present and future of the industry and have a knowledge of allied industries. The automobile includes examples of every form of manufacture. The engineer should have also a knowledge of merchandizing. If the engineer grows along the lines indicated he will fill a much larger place than he does today.

In the opinion of Colonel Alden, there has been no time when the position of the engineer was more at the parting of the ways than it is today. The engineer is now fighting the problem of the survival of the fittest. The position of the engineer in the automotive industry will be just what the engineer makes it. Engineering department rating is according to the ability of that engineering department. In just so far as the engineer *serves*, he will progress. Design requires a knowledge of all the steps of production and should include a knowledge of sales, where and how to sell. The value of an individual to an organization depends upon the amount of responsibility that individual is willing to accept. The success of the work of the Society depends upon the quality of its service to the automobile industry.

The viewpoint expressed by Mr. Moskovics was that Mr. Crane and Colonel Alden expect too much of the engineer and that such an engineer as they have in mind would, in reality, be an executive in any given organization. Weighing with due appreciation the technical side of engineering, he considers empirical engineering the most important phase. He believes that all operations must become cooperations and that the cooperation of the engineer with the production department must be through actual contact.

Mr. Beecroft subscribed to the broad conception of what an engineer should be, as stated hereinbefore.

Mr. Utz remarked that the difference between failure and success is largely the difference between dignified acquiescence and cheerful cooperation. He observed that the tendency toward maintaining a close-mouthed attitude, formerly a characteristic of the engineer, is fast disappearing and that the engineer of today realizes better the value of expression and cooperates by giving full explanation of all of his work.

Body Engineering Session

The Body Engineering Session on Wednesday afternoon could hardly have been excelled for display of enthusiasm and interest. All of the hundred or more in attendance expressed the greatest approval of the Society's recognition of this branch of automotive engineering. Papers contributed by Andrew F. Johnson and Kingston Forbes emphasized the importance of the art

of automobile body design and urged future cooperation among the men engaged in the profession. The paper read by George J. Mercer outlined the predicted trend of passenger-car body design for the coming year. The various body types were treated by Mr. Mercer and desirable color schemes suggested.

Charles A. Heergeist, the venerable carriage and body engineer, was present, his paper on the possibility of reducing body weight being read by A. P. Cardwell. This paper aroused an unusual amount of valuable discussion. The use of veneer as a weight-reducing medium has not met with favorable results apparently and it is felt that there is still a considerable field for design study to secure lighter weight.

The chassis and body engineer must cooperate to attain the proper result in this regard. It was the general expression of those present that the body must be heavy to withstand the strains resulting from chassis frames which are not stiff enough. George E. Goddard gave a very interesting description of the production methods employed in manufacturing all-steel bodies in large quantities, illustrating his talk with motion pictures.

In a general discussion after the completion of the program of papers, the body engineers recorded their interest in body standardization. Vice-President W. G. Wall served as chairman and contributed to the general discussion.

Chassis Session

At the technical session on Wednesday afternoon covering chassis design for fuel economy the principal thought in the minds of practically all the speakers was that while high fuel economy had undoubtedly been obtained in Europe, these results were by no means disparaging to American motor cars since in nearly every case the cars tested were either light-weight stock cars of designs that could not be successfully utilized in America or were cars of a size comparable with present-day practice in this country that had been materially lightened by the removal of every piece of surplus equipment. H. M. Crane, who presided, stated in his opening remarks that the public is entitled to speedy, comfortable transportation regardless of the amount of gasoline consumed. The petroleum industry, he said, had inquired about the use of low-geared cars rather than the present type of car equipped with high gears. In his opinion the reason the low-geared car had not come into general use is the fact that the public has demanded a car that will go practically anywhere without necessitating gear-shifting, which as he described it, is at best a difficult operation and in some cases resembles an acrobatic feat. Other points which were emphasized as tending to prevent the securing of more economical use of fuel were a brake adjustment by which the brakes are applied half the time, the engine consequently having to develop power to overcome this resistance, and defective gearbox and rear-axle design which causes poor lubrication due to the fact that the gearbox either does not retain the lubricant or requires the use of heavy grease.

J. G. Vincent compared the demands of economy and performance. He said that gasoline economy is not the only economy in car operation and that the three factors that determine the economy of a car are chassis design, engine design and tires. The demands for performance on the part of the user limit the engine design. Engines, he said, can be grouped into three classes, a small high-speed engine for a gear ratio of 5 or 5½ to 1, the large slow-speed powerplant suitable with a ratio of 3 or 3½ to 1, and the average engine, the proper gear ratio for which is approximately 4 to 1. There is not much difference in economy with any of the three designs. The chassis should be well balanced, special care being given to the ease with which the various necessary adjustments can be made. Great advances have been accomplished in the design of tires, and generally speaking cord tires can be depended upon to give uniform results. The practice of over-sizing tires is one that Colonel Vincent is not in sympathy with. While realizing the necessity for economy in the use of lubricating oil, this he stated cannot be carried far except at the expense of something else, the present fuel giving trouble resulting from crankcase dilution. A well balanced chassis with a smoothly operating gearbox and engine will give the maximum car economy. It was not possible in Colonel Vincent's opinion for the industry to concentrate production on a few sizes of car as the range must be sufficient to meet the demands of the purchasers. One point that is often overlooked in designing a car is the service standpoint. Service, he stated, costs in proportion to simplicity, reliability and accessibility, and all cars have offended in the last respect. The question of making gear-shifting easier is receiving consideration. The four-speed gearbox recommended by some designers is not suitable for the present car but could be incorporated very satisfactorily if the light-weight car so extensively built in Europe were adopted in this country.

A. L. Putnam presented the paper on Chassis Design for Fuel Economy which is printed elsewhere in this issue. He stated that while the engine is the most important part of the complete chassis and is far in advance of the rest of the machine due to the large amount of attention which has been paid to its development, great improvements in engine efficiency are not evident in operating under normal service conditions. He believes that opportunity is afforded the passenger car engineer to make improvements in the automobile as a road vehicle, rather than for the engine designer to improve his product. Among the factors which he emphasized as deserving attention are the use of heavy grease for lubricant, dragging brakes, and the elimination of excessive relative motion of the various parts of the automobile. Another point considered by the author worthy of consideration is the use of pneumatic tires of larger cross-section and the lessening of the air pressures stipulated for their inflation.

In the absence of William T. Magruder, his paper, entitled The Present Need for Researches on Automobiles Other Than on the Engine, was read by C. F. Clarkson. In this paper, which is printed elsewhere in this issue, emphasis was placed upon the fact that greater attention must be paid to the smaller parts and the various appliances found in automotive machinery than has been the case in the past. An outline of some of the tests of automotive machinery and parts that have been made in the mechanical engineering laboratory of the Ohio State University was presented. These covered the friction of the engine at various speeds and with different parts removed, the effect of the temperature of the jacket water upon the power and operation of the engine, the power lost in transmission and the power delivered by the rear wheels. It was hoped that tests to show the relative motions of the body and the chassis might be made shortly. In addition to outlining these tests and the manner in which they were conducted a number of results that had been obtained were incorporated in the paper.

W. P. Kennedy read a letter which had been received

by Col. A. J. Slade from the Motor Transport Depot of the U. S. Quartermaster Corps regarding the German light passenger cars that had been brought to this country. One of these cars has been rebuilt and used in courier service averaging about 110 miles daily and it was planned to do the same with a second one. The tests which have been conducted indicate that a small passenger car is more reliable for mail courier service and more economical to maintain than the heavy motorcycle with sidecar. It was believed that if further tests indicated that the light-weight car would be successful, the tread should be increased to make it conform to American practice and the general design changed to render the various units more accessible, the present design making repair work on any of the units very difficult.

Two papers were presented at this session which were not closely related to the fuel economy phase of chassis design. One of these dealt with Torsional Strength of Multiple-Splined Shafts and is printed elsewhere in this issue. In presenting the paper the author, C. W. Spicer, described a number of test which had been conducted by his company. These showed that a splined shaft has a torsional elastic limit of approximately 18 per cent less than a full round shaft of a diameter equal to the small diameter of the splined shaft. This is directly opposed to the conclusion which would be obtained superficially that the torsional strength of the multiple-splined shaft is greater than that of a full round shaft. The other paper by S. E. Slocum which dealt with a Principle of Engine Suspension, was printed in the January issue of THE JOURNAL. It describes an application of the three-point principle of support for automotive apparatus, the main object being to relieve the chassis of the vibration transmitted to it by the engine, some of the effect of vibration on the chassis being loss of power and fatigue of the metal employed. The vibrations Mr. Slocum stated are most noticeable with the closed type of body. While the three-point suspension of the engine was discussed at some length in the paper, the author stated that numerous other applications of the principle are feasible.

John G. Perrin described the results of some investigations he had made of the use of light cars abroad. In his opinion it is not possible to learn very much from these foreign cars; and there is nothing radical in their design. While these small light-weight cars are economical in the use of fuel, they would not be suitable for this country unless it should be possible to do away with the idea of purchasers here that a car should go anywhere on high gear. The engines are chiefly of the I-head type. The pockets in the combustion-chamber are small. The carbureters are practically the same as those employed in this country. The use of small cars made light weight possible. The large European cars are practically the same as those designed in the United States. The roads abroad are on the whole better than those in this country and the possibility of using the direct drive for long periods of time gives better engine economy. The Ricardo engine, the speaker stated, is the only new feature of design. This engine, which was used in British tanks during the war and is now employed in the Siddeley car, has a long trunk piston, one section acting as a guide for the other which functions as a regular piston. The use of a short piston-rod which is prevalent in this country adds to the losses due to piston friction. The British are paying attention particularly to the small cars with narrow tracks and small clearances which could not be used in this country, the engines averaging 11 to 12 hp. Two other factors which help to secure apparent high fuel economy abroad are a better grade of gasoline and the use of the Imperial gallon which is approximately 20 per cent larger than the standard United States gallon. The high-priced cars incorporate airplane features such as the use of the aluminum engine with steel sleeves, two noteworthy examples being the Hispano-Suiza and the Napier powerplants. In conclusion Mr. Perrin stated that the designers in this country are much nearer a solution of the fuel economy problem than their foreign brethren are.

In the discussion which followed the presentation of these papers it was pointed out by several of the speakers that while it is possible to get greater mileage from a gallon of gasoline abroad than in the United States, this is due largely to the lighter weight of the cars undergoing test and that if a comparison on the basis of the number of ton-miles secured from a gallon of fuel were made it would be found that the results secured in America are creditable. One of the speakers mentioned a test of the Petit Peugot car with which a 70-mile run was made at an average rate of 28 m.p.h. and 30 miles was secured from a gallon of gasoline. In commenting on the French test figures F. E. Watts stated that the French fuel economy tests did not give proper credit to the American cars and that nothing is being done abroad toward securing higher fuel economy that is not being done in this country. C. T. Myers also spoke of conditions surrounding the French fuel economy tests, stating that everything possible was done to secure the maximum ton-mileage, the stripping of the car to secure this result being carried to a point where equipment that is considered essential on American cars was removed. O. C. Berry stated that a French car weighing 5500 lb. has been driven 23.8 miles on a gallon of gasoline, while the average for the six-cylinder American car weighing 3000 lb. is 15 miles and that 20 miles is an excellent performance. There is nothing new, he said, in the English, French, Italian, and German cars which is responsible for high fuel economy and in fact in tests in this country as high as 40 miles per gallon has been obtained. He stated that properly run economy tests have a definite value and should be held yearly under the control of an engineering body. If this were done, the performance requirements being set before the tests were made, the results would have significance. At the present time the fuel situation limits the automotive industry.

H. L. Horning described some tests that had been made of an engine in which the mechanical efficiency was increased from 80 to 92 per cent by changing the grade of oil. If the horsepower required to overcome friction in an engine is to be reduced, attention must be given, he said, to improving piston design, since the friction between the piston and the cylinder walls is responsible for 50 per cent of the power lost in overcoming friction. He said also that pressures as high as 10,000 lb. per sq. in. are developed on the oil film between the piston and the cylinder walls.

COMMERCIAL AVIATION SESSION

Vice-President Glenn L. Martin, who was chairman of the Commercial Aviation Session, presented a most instructive paper on Commercial Aerial Transportation. He stated that its success depends upon the operative personnel, the airworthiness of the craft and weather conditions. As evidence of commercial practicability, mention was made of the success attained already in expediting delivery in the United States mail service, Mr. Martin reviewed the service already given by the 17 airplanes

now in use in the Forestry Department. The need for aerial terminals was emphasized and the benefits that a town or city derives from being located on an air route were described. It was stated that Federal regulation is the only solution of making commercial aerial transportation a success.

The matter of aircraft insurance was discussed and the basis upon which premiums can be figured was said to be dependent upon the capability of the pilot, the efficiency of the aircraft and the type of engine employed. Mr. Martin commented upon the present conservative attitude of the Government, and averred that commercial aviation is here, and must be developed and popular prejudice and skepticism overcome.

Prof. E. P. Warner's paper on Commercial Aviation in Europe was illuminative and afforded an opportunity for better comprehension of the remarkable progress and accomplishment made there in commercial lines. Reviewing the present European routes now in regular or partial operation, he stressed the essentialness of the attitude of the press in general being favorable if commercial aviation is to become wholly successful.

The airship appears most practical for long-distance service to Professor Warner, and he mentioned the possibility of cities and towns growing up around "air ports." The cost of airship travel was specified as 15 cents per mile, or less, although it is difficult to figure costs and necessary charges because so few data on depreciation of equipment are available.

Regarding successful operation, much depends upon the efficiency of the ground personnel and organization. It is present practice to send out to aviation pilots by radio telegraph hourly weather warnings which give the height of the clouds, the degree of fog at ground level and details of visibility.

Following a discussion of the matter of Governmental subsidies, Professor Warner described the different kinds of machines and stated many of the advantages and disadvantages of single and multi-engined aircraft, his opinion being that multi-engined machines are necessary, especially for extremely large units. Slides were then shown of the different types of airplane now in commercial use.

In the discussion which followed, R. H. Upson insisted upon the necessity of cooperation between the operative and manufacturing departments of aviation; Ladislas d'Orcy stated further considerations in regard to Governmental subsidies; and E. A. Sperry gave interesting data on the penetrating power of beams from searchlights as applied to guiding air pilots to landing fields and terminals.

The Aerial Transportation of the Immediate Future was comprehensively considered by Ralph H. Upson in presenting his paper on this subject. He gave an outline of the fundamentals and divided the subject into a discussion of what we have at present and what must be considered for the future, stating that it must be left to the inventors as to how far they can go in providing equipment. The first question regarding new equipment is, "Will it work?" The next, "Is it safe?" Safety was described as being purely relative and the statement made that there is no such thing as absolute safety. There is no need to expect danger. We must have both speed and safety and making aerial equipment safe is well worth while, no matter at what expense of money and effort. As to whether commercial aviation can be made to pay, economically and so far as society as a whole is concerned, this is comparatively a relative question and depends upon the length of haul and the mileage cost. Charts were shown and methods of obtaining basic costs described, together with formulas and coefficients so obtained. These were worked out for both airplanes and airships. Other charts giving the yearly operating costs of airships, their capital expense and cost curves, and the size of airships required for given distances of cruising radius were shown and explained. The speed and cost data for cargo of varying time value carried over various distances, and the cost of freight transportation, were presented in additional charts.

In the discussion which followed, the merits of the airship and those of the airplane were compared. Professor Warner enumerated the main requirements for successful aerial transportation at night.

L. B. Lent, of the United States Air Mail Service, gave a résumé of the performance attained in American regular aerial mail service lines and stated that the only excuse for multi-engined airplanes is to enable them to travel from terminal to terminal without the necessity of forced landing. For this, his opinion is, from one to three engines are needed. Maintenance and repair costs are heavy items and merit careful consideration. The work of the Society can best be devoted to clearing up airplane design and making airplanes more reliable. Commercial aviation is a real practical proposition, but greater ability to fly above the clouds and to locate terminals is needed and for this it is necessary that aerial navigation instruments be improved and additional ones provided.

The paper presented by S. W. Sparrow gave in succinct form the Relation Between the Compression Ratio and the Thermal Efficiency of an Airplane Engine, the result of an investigation by the Bureau of Standards which was sponsored by the National Advisory Committee for Aeronautics. Every effort was made in this investigation to measure the engine performance so completely as to make possible an analysis explaining not only the results of this series of tests, but forming also a sound basis for predicting the effect of changes in compression ratio on the thermal efficiency of any engine. The experimental work has not been completed, but the more salient results were presented.

The tests for which an eight-cylinder airplane engine was used, were made in the altitude chamber of the dynamometer laboratory in order that typical altitude conditions of air temperature and pressure might be obtained. The data reported were secured at full load, at an engine speed of 1600 r.p.m. The paper includes considerable technical detail, the results being given in various charts and summaries that should be considered in relation to each other for thorough comprehension. It is planned to publish the paper in full in an early issue of THE JOURNAL. One point brought out is that the gain ensuing from the employment of the higher compression ratios increases with increase in altitude. This latter effect is due solely to the increase in power and the resulting smaller ratio of friction to brake-horsepower. Hence, the same condition would result from supercharging or from any other method of efficiently increasing the power developed. The fuel used in these tests was aviation gasoline.

Following Mr. Sparrow's paper, it was stated that the Bureau of Civil Affairs, at Washington, has plans for airdromes, layout and the like, and is desirous of cooperating fully with the Society in matters relating to aircraft development and operation. It was announced also that the National Advisory Committee for Aero-

nautics has prepared a tentative program for a contest in the interest of commercial aviation which it is hoped will materialize. An airway between Washington and Dayton, Ohio, has been proposed, equipped with hangars and necessary material that will permit flying at night, and over which an inexperienced pilot can make his way in one day.

Fuel Session

The intense interest of the members in this feature of the Annual Meeting of the Society, held Jan. 13, 1921, was manifest throughout its continuance by the large attendance at both the morning and afternoon sessions, by the close attention paid the speakers during the presentation of their excellent and comprehensive papers and by the spirited discussion which followed.

President Vincent was chairman at both sessions. At the opening of the morning session he made some very pertinent remarks relative to the fuel situation in general and to the necessity of active cooperation with the oil industry in the solving of the fuel problem. Following his remarks, he called upon Charles F. Kettering to present the subject of Fuel Research Developments.

Mr. Kettering first referred to the remarkable progress in fuel research work during the past year and then stated that there is a "dead-line" in the utilization of fuel in internal-combustion engines beyond which progress cannot be made. The automotive industry must cooperate with the oil industry and find out what and where this dead-line is; it must know the end-point of fuels obtainable five years hence.

The two distinct divisions of the fuel problem are the fuel distribution in multi-cylinder engines and the chemical changes that occur inside an engine cylinder during combustion. Considering and explaining an elementary case, that of the combustion of hydrogen and oxygen, the components of combustion energy were stated to be gravitational, kinetic and barometric, and these, in turn, were considered and analyzed in considerable detail, with the aid of charts, formulas and diagrams illustrative of molecular structure. Other charts showed the normal combustion of propane, its abnormal combustion such as occurs during knocking and the method of calculating the knocking value of a fuel.

In Mr. Kettering's opinion, regarding any theory, the greatest difficulty is to obtain a proper conception of the terms employed in its development and to apply this knowledge correctly. This idea was amplified and the strange fact that substances of apparently diverse composition are in reality made up of the same chemical constituents was illustrated by several exhibits of substances that have been chemically analyzed. That engineers must think of heat in terms of molecular velocity was emphasized and it was stated that the proper fuel mixture for an internal-combustion engine is not dependent upon the molecular construction of the fuel.

Engine friction is one of the most difficult problems with which an engineer must deal and it must be reduced in some manner. The present need is to burn less fuel per car-mile. Numerous slides of indicator cards obtained when using the different available fuels in an internal-combustion engine were exhibited and the different characteristics of the performance of each fuel explained.

Previous to calling upon Frank A. Howard to present his paper on the Volatility of Internal-Combustion Engine Gasoline, President Vincent remarked that the fact that nothing went wrong in the performance of the single-cylinder Liberty engine, with which he is so intimately connected, indicates that a large portion of the difficulties experienced at present is caused by poor distribution of the fuel to the various cylinders in a multi-cylinder engine. Mr. Howard then presented his paper.

After stating that the meaning of the term "gasoline" seems to be generally misunderstood for the reason that it has been assumed that gasoline is, or ought to be, the name of a specific product, Mr. Howard said that it is not and never has been a specific product and that although gasoline has a definite and generic meaning in the oil trade it has no specific meaning whatever. It means merely a light distillate from crude petroleum. Its degree of lightness, from what petroleum it is distilled and how it is distilled or refined are unspecified.

Specifically, "gasoline" is the particular grade of gasoline which at a given moment is distributed in bulk at retail. It can be defined with reasonable precision as being the cheapest petroleum product acceptable for universal use as a fuel in the prevailing type of internal-combustion engine. The author placed emphasis on the three factors of this definition: (*a*) the cheapest product, (*b*) its universal use and (*c*) the prevailing type of internal-combustion engine.

Mr. Howard's purpose in this paper is to clear away some of the haze which surrounds the word "gasoline" and, with regard to what volatility is with reference to engine gasoline to show how much of the difficulty is inherent in the fuel and how much of it arises from the failure of automotive engineers, collectively, to attain a high average of perfection in the handling of the fuel.

Ordinary engine gasoline of the grade now sold possesses sufficient inherent volatility to take and maintain the condition of a gas at a temperature at or below average intake-manifold temperatures. Manifold condensation seldom, if ever, occurs and cylinder condensation is even less probable. The phenomena answering to these names are in fact mainly the visual evidences of the failure of the vaporizing device to function. Fuel once vaporized must stay in that condition; hence, if liquid is found beyond the vaporizer, it reached there as a liquid.

These conclusions are based on an examination of the fuel itself. The volumetric proportions of a combustible mixture are considered in detail in this paper and the physical meaning and measurement of volatility are fully discussed, tables of vapor tensions being given and the special apparatus developed to determine the vapor tension of gasoline being exhibited and described. Following this a full discussion of the requirements for full utilization of inherent volatility is presented, the conclusion reached being that the problem resolves itself into the further development, improvement and wider use of the hot-spot.

The next paper presented was that of C. A. Woodbury, the subject being the Nature of Flame Propagation in a Closed Engine Cylinder. The possibilities with regard to suppressing knock in an internal-combustion engine cylinder were discussed. The photographic method was used to study flame propagation. Gas was exploded in a cylinder of constant volume which had no piston and the photographs were made through a glass window. A photographic diagram of the apparatus was shown and explained and a table giving the velocity of the flame movement for various mixtures of acetylene and air was presented. Numerous photographs of the flame movement of different fuels were then shown and commented upon.

The difficulty of producing detonation in a small combustion-chamber was mentioned and the statement was made that the tendency to detonate is not increased by an increase of temperature.

At the afternoon session, the first paper was presented by Reuben E. Fielder, entitled Air-Temperature Regulation Effects on Fuel Economy.

In connection with the present fuel shortage, the problem of securing a much higher degree of economy with existing equipment and that of future design are of nearly equal importance. The fuel bill of the Fifth Avenue Coach Co., New York City, constitutes its second greatest item of expense, and for this and many other reasons this company is constantly experimenting with devices of various kinds to improve fuel economy. Its present thermostatic temperature control for the carbureter appears to afford greater possibilities of fuel saving than anything else that has been brought to its attention and Mr. Fielder presented the results of tests of this device.

A diagram of the device was shown and explained and a detailed description given of the thermostat. Comparative tests were made with and without this thermostatic-control device, using the same engine, carbureter and similar equipment, under the same conditions of atmospheric temperature. The results were summarized and illustrated in the tables and charts that were exhibited.

The effect of atmospheric temperature variations was studied in connection with comparative fuel distillation curves, with reference especially to the effect of variation in manifold temperature on fuel economy and torque developed, in an effort to obtain data as to what constitutes a desirable manifold temperature. The necessity of considering the important matter of volumetric efficiency is evidenced by the gain of the thermostatically controlled equipment over the standard equipment, much of this gain being due to an increase in volumetric efficiency with the cooler air.

The company believes that the principle of thermostatic temperature control is correct, but that its detailed application is still a matter for further experiment. At certain periods of each year the average internal-combustion engine functions with the minimum amount of trouble, because at such times the atmospheric temperature is right. The idea is to select such a period and to standardize it for use throughout the remainder of the year.

A. L. Nelson presented an unusually interesting and comprehensive paper on the Fuel Problem in Relation to Engineering Viewpoint. He stated that it is believed that never before in the history of the Society of Automotive Engineers has a single problem been so universally studied as the fuel problem that is confronting the industry today. It is also believed that never before has the industry had a problem which includes such a wide scope of work. The solution calls for the service of every class of engineer, inventor and scientist.

The paper does not attempt to give highly scientific information; its real purpose is to appeal for a broader viewpoint and give illustrations and tests which show that the solution of a problem may lie in an entirely different method than that which often becomes stereotyped by sheer usage, rather than by its specific merit. In the solution of the fuel problem we undoubtedly will have to change some of our old habits, replacing them by studiously worked out viewpoints. The further object of the paper is to seek the correlation of the experience of the entire engineering fraternity, to obtain the comments of its members and receive any suggestions they may offer.

After giving recognition to the cooperation and assistance already received and making general comments upon the desirability of radical changes in viewpoint, Mr. Nelson entered upon a discussion of the engine power required to drive a car at constant speed and the effect of using higher piston compression ratios, illustrated by a table and charts, with a view to demonstrating the value of modified viewpoint. In like manner he discussed the constant-clearance aluminum piston and the fuel vaporizer. The basic principles of the engine used in testing were next considered and copiously illustrated, together with the apparatus used in the dynamometer and practical driving tests that were made. Charts show the percentage comparison of results and these are explained.

After a discussion of ideal economy, it is stated that the tests show that an absurd waste is rampant in the present method of applying the indicated engine power and that this subject should be studied from every angle. A close study from the brake-horsepower standpoint may justify changing both transmission and rear-axle drive ratios. The latter combinations, together with engine developments, look the most promising at present. The progress we make will be measured by the extent to which we expand our engineering viewpoint.

Dr. H. C. Dickinson gave a résumé of the fuel study made by the Bureau of Standards. In connection with the effect of compression on a dry mixture, curves were shown to illustrate that gasoline vapor compresses when "dry." Detonation was evident when using one spark-plug and there was no detonation when using two spark-plugs. After preliminary experiments of the nature already indicated, a pressure indicator was used, at pressures just on the verge of detonation, to find the exact point where detonation occurs. Slides were exhibited to show the position of the piston with reference to its center position, with one spark-plug and with two spark-plugs; and the effect of spark advance on maximum explosion pressure and brake-horsepower, using one spark-plug.

The Discussion

The discussion which followed the presentation of the fuel session papers included comment by many members on the debatable points that had been raised. It is expected that this discussion will be printed in full in an early issue of The Journal, but its trend can be indicated by quoting briefly some of the important ideas expressed.

Among these was the belief of L. M. Woolson that, in place of needing a change in viewpoint such as was advocated by A. L. Nelson, the necessity is for closer concentration on the detail problems of the automotive industry. He stated that it is perfectly possible to reduce the gasoline consumption of 1.125 lb. per b.hp-hr. at 1000 r.p.m., attained by Mr. Nelson in one test, to about 0.93 lb. per b.hp-hr., which represents a gain of something like 20 per cent in gasoline mileage, by constructing carbureters that will give a lean mixture under average driving conditions, and that this can be done without diminishing acceleration or wide-open pulling ability.

Regarding fuel vaporization, Mr. Woolson's opinion is that the ability to accelerate well in cold weather without pulling the choker soon after starting does not prove that sufficient heat has been furnished to the mixture under average driving conditions, and that it would depend upon how rich a mixture the carbureter was set to furnish at the time. He believes that actual intake mixture

temperatures should be referred to in discussing methods of fuel vaporization, instead of referring to car performance in a general way or to other less specific data. There is a certain desirable range of mixture temperatures which probably will apply to all engines under the same conditions and automotive engineers need to know what that temperature range is. He believes that the desirable temperatures will be found to be about 100 deg. fahr. above those obtaining in the average intake-manifold. He believes also that there will be considerable variation in future opinions as to the significance of actual manifold temperature measurements and concurs with F. A. Howard in the opinion that it is not desirable to heat the air unduly but that it is necessary to apply fairly high temperatures to the fuel. In one case there may be an average mixture temperature of 120 deg. fahr. and a relatively poor degree of vaporization, and in another case, with the same average temperature, almost complete vaporization. Mr. Woolson thinks that the next step must be to determine the best average mixture temperatures under different conditions and believes the suggestion of H. L. Horning that these should be determined in terms of carbureter efficiency is really constructive.

Herbert Chase urged consideration of the work of A. L. Nelson toward obtaining better fuel economy under part-load conditions, recommending that this procedure be developed further because most efforts in this general direction are made under full load. He stated also that the average car wastes about 30 per cent of the fuel that is supplied to it and that automotive engineers should be able to prevent a large part of this waste.

The direct question was asked by J. D. Gill, a representative of the oil refining industry, as to what the automotive industry specifically wants as fuel for internal-combustion engines. He called attention to the possibility that detonation is due to a lack of the requisite amount of fuel in some certain cylinder in a multi-cylinder engine and suggested the introduction of a fuel reservoir in which pressure can be built up, in a similar manner to that used in water-flow systems, thus furnishing continuous fuel flow with carbureter pulsations practically eliminated.

F. A. Howard mentioned that successful fuel economy results appear to depend upon the juggling of the three factors, surface, time and heat.

A study of the carbon monoxide content of internal-combustion engine exhaust gases by the Bureau of Mines, as the result of tests of about 100 automotive vehicles, in connection with the adequate ventilation of the vehicular tunnel now being constructed under the Hudson River between New Jersey and New York, was presented by A. C. Fieldner and slides were shown of the apparatus used and the curves and values obtained from test results. The chemical control of exhaust gases and carbureter settings was advocated. In connection with exhaust gas content, E. A. Sperry stated that no trace of carbon monoxide had been found in the exhaust gases of the Diesel engines in use at the United States Navy Yards.

The subject of the design of pistons, piston-rings and grooves, with special reference to proper shape for racing-car pistons, the desirable location for piston ribs and allowances for expansion, was discussed by William C. Davids.

T. C. Menges stated his experience in running stationary engines on kerosene, they being equipped with a throttling governor, a high-tension magneto and a spark-plug in place of the ordinary make-and-break. The great difficulty has been to run such an engine successfully with a light load or with no load. He advocates locating the carbureter above the inlet valve of the engine; in this position not as hot a manifold and not as hot an intake of air are required, better volumetric efficiency is obtained and the engine runs more satisfactorily. The inlet manifold should be short, with few bends. Mr. Menges has been able to run these engines on kerosene without a hot-air manifold and has not had to use water to reduce knocking, probably because the vapor enters the engine fairly cool. The fuel nozzle should be located next to the edge of the butterfly throttle-valve in place of being a long distance from it as is the case with most automobile carbureters. If so located, the butterfly throttle-valve is almost closed when the engine is running with no load. The small amount of air that passes into the carbureter must pass the fuel nozzle; this breaks up the liquid fuel and forms an explosive mixture. Mr. Menges believes that if the liquid kerosene could be broken up into a fine enough mist, an engine would start cold on kerosene. On the contrary, if the kerosene is not thoroughly broken up, an excess amount of heat will be required to vaporize it.

H. L. Horning said that the proposed program of co-operation between the Society and the American Petroleum Institute comprised the four stages of gathering, classifying, analyzing and using the data available, that a large portion of the first two stages had now been covered and that what is needed at present is to go more deeply into the work of the third and fourth stages.

Stating that the matter of carbureter efficiency had been obscured, he exhibited and explained charts and formulas illustrative of his beliefs, especially to the effect that indicated mean effective pressure is the net return for whatever energy may have been expended, and showed the derivation of a formula for determining what he terms "gasification efficiency."

Regarding flame propagation, his theory is that of maximum area and he believes that the consumption of a certain volume of fuel within a minimum length of time should not be attempted.

Highway Session

At the Highway Session held Wednesday afternoon Past-President H. W. Alden presided. His opening remarks on Automotive Obligations Toward Highway Development are printed elsewhere in this issue. In this address Colonel Alden emphasized the fact that the automotive industry is responsible for other things than the actual building and selling of motor cars and pointed out that the correct solution and proper arrangement of railroads, highways and waterways in the general function of merchandise transportation will have a wonderful effect on the future of the entire automotive industry. The railroads are at the present time doing a great amount of less-than-carload short-haulage work, for which they are not so well equipped as is the motor truck, with the result that freight cars average little better than 25 miles per day, due to this fact and terminal delays.

The first paper of the session was by W. E. Williams on Highway Construction. In presenting the paper, which is printed elsewhere in this issue, Mr. Williams took up the three types of road, which are brick, asphalt and concrete, and discussed their various defects. In the brick road the most prominent defects are the variation in height of the bricks and the bond between them, which results in the corners breaking down in service from the effect of the toe calks of the horses and the steel tires of the vehicles which they draw. This variation in

the road and also the racing of the gears which follows the dropping of the wheel into a depression in the roadbed, produces a jarring effect upon the vehicles; accordingly vehicle owners should object to the use of brick. Another objection to a brick road laid on a concrete foundation is that such a road costs more than a concrete slab of the same total depth and the beam strength necessary in a road surface to distribute the load is limited in a brick road by the thickness of the concrete sub-base. For example, in a road made up of 6 in. of brick laid on a 4-in. concrete sub-base the beam strength is as the square of the depth of the brick or 36, while if a concrete road having the same depth as the concrete sub-base with a brick top, or 10 in., were used, the beam strength would be 100, or approximately three times as much. The real factor of construction of a road is not the surface but the soil. The asphalt road has merit for horse-drawn vehicles but possesses the same beam-strength weakness as a brick road and also costs more to lay than a concrete road of similar depth. Under traffic this road assumes a wavy surface and the hammer-blow, which term Mr. Williams preferred to impact, produced by the vehicle falling from the crest of one of the waves into the valley destroys the sub-base and thus leads ultimately to the destruction of the road. Asphalt should not be considered, particularly with soils subject to moisture.

A. T. Goldbeck spoke on Government Highway Research. He specified the subgrade as the important factor in road building. There are three types of road failure; that produced by the horse-drawn vehicles which affect the surface only, the raveling action of the surface caused by rapidly moving automobiles, and the structural failure in which both the subgrade and the surface are affected. The various researches which the Government is conducting in the subgrade fundamentals and impact tests, and the way in which they are conducted were explained. In Mr. Goldbeck's opinion it is desirable to decrease the load per wheel but still carry the same gross load as has been carried with steam locomotives. The result greatly desired is that giving the least cost of the motor truck and of the building and maintenance of the road. In conclusion Mr. Goldbeck urged cooperation between the Society and the highway engineers.

H. E. Breed was the next speaker, his topic being Variable Factors in Highway Design. There are, he said, two factors in transportation, the vehicle and the road; and in case of trouble each blames the other, the roads stating that they failed because the vehicles pounded them too hard and the vehicles replying that they are impeded because the roads will not sustain them. To solve the problem the mutual dependence of both factors must be realized. In designing a road the first thing to be specified is the type of pavement to be laid and this is really determined by the volume and character of the traffic which will use the road, although cost, soil conditions, availability of materials and other considerations influence the decision. The greatest damage is done to roads by impact, that is by the pounding of the load upon the road, and this is accentuated by any unevenness in the road or in the tire of the vehicle. Part of the tire trouble is due to carelessness of motor-truck users, although it was pointed out that even if the motor-truck user were educated not to overload his truck beyond its capacity, it would be necessary to supply smooth broad tires that would reduce the damage from impact and also distribute the weight of the load over the road surface. The stability of the soil determines the strength of the foundation used and this stability varies inversely with the moisture content. Surfacing and maintenance are two other variables that require consideration. Special emphasis was put upon the fact that to have a good system of roads it is necessary that politics be divorced from State Highway Departments.

In opening the discussion A. F. Masury described apparatus that has been developed by the International Motor Co. for measuring the effect of inequalities in the road surface on the trucks, illustrating his remarks with slides of the apparatus and also the records which were made on a continuous sheet of paper.

S. W. Williams of the Federal Highway Council emphasized the desirability of having organizations such as the Society, the American Automobile Association and the National Automobile Chamber of Commerce cooperate in an effort to overcome the difficulties and handicaps in the successful development of a highway system which existed at the present time. In his opinion the highway should be fitted to the vehicles that pass over it, rather than limit the vehicle by the character of the highways that are built. In this connection he brought out the point that it is not possible to develop either a highway or a vehicle 5 or 10 years in advance. The highways have an earning capacity and transportation needs will be the factor governing road and vehicle development. The term "drainage," he thought, is misused, the necessity being to keep moisture out of the road, not to take it out after it has gotten in. If the roads were thoroughly dry, practically any weight could be sustained and all talk about limiting the size of trucks would disappear.

A representative of one of the asphalt companies took exception to W. E. Williams' condemnation of asphalt as a road material, stating that his remarks were not borne out by the service record of asphalt on both rigid and non-rigid bases. He also cited instances of the laying of an asphalt wearing course over a road that had been broken down by heavy motor-truck traffic, having salvaged the road at a comparatively low cost.

Social Features

To describe the Carnival of 1921 with the adjectives usually prevalent in the average engineer's vocabulary must be acknowledged impossible. One would have to be endowed with the versatility of a theatrical press agent or the cunning of P. T. Barnum to do it justice. The large ballroom of the Hotel Astor was temporarily transformed into a Parisian boulevard with its colorful sidewalk cafés where food and drinks (typically American) were available. A fashion show with Broadway manikins was arranged for the ladies and appreciated by them and the men. A staged argument between two waiters which ended in a duel was nearly ruined by Harry Horning who wondered what it was all about. The dance orchestra apparently pleased, for they repeatedly begged the devotees of the fox-trot for rest periods, and were not allowed their freedom until 3 a. m. To say that the S.A.E. ladies smiled, danced, and dressed suitably means that they reached perfection. The folk dances rendered by accomplished artists were dainty and pleasing.

The Carnival Committee headed by H. G. McComb accomplished a most successful result and are to be congratulated. The arrangements for an event like the Carnival require weeks of work and thought and the Committee always gave their time unreservedely. The Astor Ballroom was transformed under Mr. McComb's direction for the entertainment and pleasure of the members in a manner never equalled for novelty, effectiveness and beauty.

The Officers of the Society

At the Annual Meeting of the Society held last month, a President, a First Vice-President, five Second Vice-Presidents and two Councilors were elected and the Treasurer was reelected. In addition to these officers the three Councilors elected at the 1920 Annual Meeting and the last Past-President are voting members of the Council for 1921. To fill the vacancy caused by the election of only two Councilors instead of three as authorized by the Constitution, Glenn L. Martin was chosen by the Council. The careers of the men who will guide the work of the Society this year are outlined in the following paragraphs.

David Beecroft

President Beecroft was born in 1875 at Marnock, Ont., Canada. In 1893 he was a teacher at a country school. Prior to that time he attended the Barrie Collegiate Institute. Beginning in 1895, he was an instructor for six years at a St. Thomas, Ont., school, being connected also with the editorial department of the *St. Thomas Daily Times*. Leaving St. Thomas in the summer of 1901, he was engaged by the *Chicago Daily News* as an advertising solicitor.

In 1902 he became editor of the *Automobile Review*, which had been issued monthly in Chicago. It was changed at once to a weekly. In 1904 Mr. Beecroft was assistant editor of *Motor Age*, with which he has been connected in various capacities since that time. In July 1911, he undertook, in addition to the *Motor Age* work, the position of managing editor of *The Automobile*. In November of that year he became also managing editor of *Commercial Vehicle*, and in February, 1914, he took a similar position with *Motor World*. At the present time he is directing editor of the Class Journal Co., New York City.

Since entering the automobile industry Mr. Beecroft has been particularly active in automobile contest work. He drafted the first stock-car racing rules. He has been closely identified with the American Automobile Association Contest Board for many years.

Mr. Beecroft became a member of the Society in 1911 and has served on the Council for four years. He has been a member of the Meetings Committee for five years and chairman for four years.

H. L. Horning

First Vice-President Horning secured his early training in the modern classical course in Carroll College Academy and the scientific course at Carroll College, both at Waukesha, Wis. In 1901 he was in the chemical laboratory and operating department of the Milwaukee Gas Light Co., and later served for two years in the steam engineering department of the Crane Co. From 1904 to 1906 he was head of the mechanical engineering department of the Modern Steel Structural Co., his most important work at that time being the construction and mechanical operation of the Duluth steel bridge, one of three structures of the kind in the world. In 1906 he established the Waukesha Motor Co.; he has served as its chief engineer and general manager since that time.

Mr. Horning is a member of the American Society of Mechanical Engineers, and of the Association for the Advancement of Science. He was elected a member of the Society of Automobile Engineers in 1910 and through his connection with the Society of Tractor Engineers and the National Gas Engine Association was active in the movement which resulted in changing the name of the Society to Society of Automotive Engineers.

He was chairman of the automotive products section of the War Industries Board, Council of National Defense, during the war. He served as Chairman of the Design Committee of Engineers that laid out the engines for the Class B and AA military trucks. He was the first chairman of the Tractor Division of the S. A. E. Standards Committee and was a member of the first Oil and Fuel Committee established by the Council of the Society.

Truck and Tractor Engines was the subject of a paper he presented in 1916 at a Mid-West Section meeting. At the 1917 Annual Meeting he presented a paper on the Ultimate Type of Tractor Engine and at the 1917 Semi-Annual Meeting gave a paper on the Farm Tractor as Related to the Food Problem. He also presented a paper on Tractor Engines and Fuel Limitations before the Detroit Section in 1919.

As a representative of the Society Mr. Horning accompanied the National Screw Thread Commission on its trip abroad during July, 1919, to make a study of foreign screw-thread practice. Together with Dr. Dickinson of the Bureau of Standards he visited Dr. Dixon of Manchester University and brought back to this country a statement of the theory of engine knock and detonation.

He proposed and aided in the movement to bring the automotive and the petroleum industries together for the purpose of dealing promptly with the fuel question. Mr. Horning was chairman of the Committee on Utilization of Present Fuels in Present Engines, whose first report was presented at the meeting of the Society held last summer. He also proposed the plan of inviting leading internal-combustion engineers of Europe to visit this country to take part in meetings of the Society.

B. B. Bachman

Second Vice-President Bachman, representing motor-car engineering, was born Oct. 4, 1886, educated at grammar school, night school and under a private tutor, and started his business experience in 1900 as a tracer. The next 10 years were spent as tracer, detailer and designer with the Enterprise Mfg. Co., and the Falkenau Sinclair Machine Tool Co., both of Philadelphia, and the Autocar Co., Ardmore, Pa. His entire automobile experience has been with the last named company, which was a builder of passenger vehicles until 1912 and of commercial vehicles from 1907 to date. Starting with this company in February, 1905, he became assistant engineer in 1909 and engineer in 1914.

He was elected a Junior Member of the Society in 1910 and transferred to Member grade in 1912. Mr. Bachman is a member of the American Society of Mechanical Engineers, American Society for Testing Materials and the Institution of Automobile Engineers. When the Pennsylvania Section was organized he was one of the charter members and served as its first secretary. He was identified with the work of the Truck Standards Division in 1911 and has been Chairman of the Standards Committee since 1918. At present he is a representative of the Society on the American Engineer-

DAVID BEECROFT

ing Standards Committee. He was elected to the Council in 1916 and again in 1918. In 1919 he was elected First Vice-President of the Society. As a member of the Truck Standards Division Mr. Bachman participated in the formulation of the specifications for military trucks for the Quartermaster Department, and afterwards was engaged at irregular intervals in the design of Class B and Class A military trucks. In the design of the Class A Military Truck, he was chairman of the committe on design.

At the 1913 Annual Meeting Mr. Bachman presented a paper entitled Comparative Results with Solid and Pneumatic Tires on Light Commercial Vehicles, and at the 1914 Annual Meeting he treated the subject of Double-Reduction Live Axle. At the 1919 Motor Truck Meeting he gave an address on Pneumatic Tires for Trucks.

E. A. Johnston

Second Vice-President Johnston, representing tractor engineering, was born at Brockport, N. Y., Aug. 1, 1875. After receiving a public school education he entered the Chicago Business College. From 1890 until 1894 he was employed by the Johnston Harvester Co., Batavia, N. Y., serving in all departments including wood and metal pattern-making, blacksmithing, machine shop and foundry. In 1894 he accepted a position as pattern-maker with the McCormick Harvester Co., and has been continuously employed by its successor, the International Harvester Co. and its subsidiary organizations as machinist, designer, experimental engineer, foreman, superintendent and manager of the experimental department. He now holds the position of manager of the experimental and gas power engineering departments.

Mr. Johnston is the chairman of the Tractor Division of the Standards Committee. He has had a very wide experience in electrical and mechanical engineering and research work related thereto. He was elected a Councilor at the 1919 Annual Meeting.

Henry M. Crane

Second Vice-President Crane, representing aeronautic engineering, was born on June 16, 1874. He received his education in private schools with a final year at Phillips Exeter Academy, graduating in 1891. He was graduated from Massachusetts Institute of Technology in 1895 with the degree of Bachelor of Science in Mechanical Engineering and in 1896 with a similar degree in Electrical Engineering.

After graduating he joined the laboratory force of the American Telephone & Telegraph Co. in Boston and worked there two years. In 1898 he was transferred to the engineering department of the Western Electric Co. in New York City, where he worked first on the preparation of telephone switchboard installation specifications and later on the development of apparatus and circuits. In 1905 he left the engineering department to become engineering assistant to H. B. Thayer, general manager of the company, and finally resigned from the company in 1906.

In 1906 Mr. Crane organized the Crane & Whitman Co. in Bayonne, N. J., for the development of gasoline automotive machinery and especially motor cars. This company later became the Crane Motor Car Co., and in 1914 was consolidated with the Simplex Automobile Co. He was president of the Crane Motor Car Co. and Vice-President of the Simplex Automobile Co.

In 1916 the Wright Martin Co. was organized and absorbed the Simplex company. Mr. Crane became vice-president in charge of engineering and remained in this position after the reorganization of the company as the Wright Aeronautical Corporation, about Jan. 1, 1920. He resigned from the latter company on March 15, 1920, since which time he has not been engaged in any regular business but has done some consulting work. Mr. Crane has taken a prominent part in the work of the Fuel Committee of the Society, and is Chairman of its Research Committee and Aeronautic Division.

Joseph VanBlerck

Second Vice-President VanBlerck, representing marine engineering, was born in Oudenbosch, Holland, Aug. 13, 1874. Early in 1902 he came to Detroit, where he continued his engineering work and began the construction of internal-combustion engines. In 1909 the VanBlerck Motor Co. was organized and later a factory was built at Monroe, Mich., for the production of the VanBlerck marine and commercial gasoline engines. Mr. VanBlerck acted as president and general manager of this company until early in 1919, when he formed his present connection with the Wellman-Seaver-Morgan Co., Akron, Ohio, organizing the motor division of that company for the building of truck and tractor engines. Mr. VanBlerck is also President of the J V B Engine Co., of Cleveland. He has been a member of the Society of Automotive Engineers for five years and during the past year served as Chairman of the Marine Division of the Standards Committee.

T. C. Menges

Second Vice-President Menges, representing stationary internal-combustion engineering, was born in 1872 at Prairie du Chien, Wis. After graduating from high school in 1890 he attended the University of Wisconsin until 1893, when he left to enter Cornell University as a student in mechanical engineering, being graduated therefrom in 1894.

His business career began with the Otto Gas Engine Works at Philadelphia in 1894, where he was assistant superintendent for two years, leaving to accept the superintendency of the Winona Mfg. Co., Winona, Minn. After building gasoline tractors at Winona he resigned in 1897 to engage in gold mining and for the next two years was manager of the Lyle Mining Co., Rainy Lake, Minn. Mr. Menges' connection with the internal-combustion engine industry has been continuous since 1898 when he became vice-president and general superintendent of the Davis Gasoline Engine Co., Waterloo, Iowa. In 1900 he was appointed general superintendent of the Waterloo Motor Works and held that position for eight years. For the next two years he was chief engineer of the William Galloway Co., also of Waterloo, and in 1909 he was appointed general superintendent of the Associated Manufacturers' Co., a position which he still holds. Mr. Menges was elected to Member grade in the Society on April 17, 1917. He is a member of the American Society of Mechanical Engineers and was vice-president of the National Gas Engine Association, the predecessor of the Gas Engine and Farm Power Association.

J. G. Vincent

Past-President Vincent was born at Charleston, Ark., Feb. 10, 1880. His education was received at a country school near Pana, Ill., and the Cote Brillinte Grammar School in St. Louis. At the age of 17 he left his father's farm and entered the service of Smith Vincent & Co., a firm of commission merchants of St. Louis. His natural

H. L. HORNING

B. B. BACHMAN

E. A. JOHNSTON

J. G. VINCENT

JOSEPH VAN BLERCK

T. C. MENGES

H. M. CRANE

inclination toward mechanics led him to a local machine shop where he worked as a machinist's helper by day, attending night school and pursuing a correspondence course in engineering at the same time. He became a machinist and afterward a toolmaker, joining the forces of the Universal Adding Machine Co., St. Louis, in that capacity in 1902. After a few months he was given charge of the toolmaking department. In 1903 he became connected with the Burroughs Adding Machine Co., which at that time was located in St. Louis. Shortly afterward this company's plant was moved to Detroit, and Mr. Vincent was promoted to the position of superintendent of inventions. He organized and had charge of a large inventions department, in which most of the improvements on the Burroughs adding machine were conceived or made practical.

In 1910 Mr. Vincent became chief engineer of the Hudson Motor Car Co. Since 1912 he has been associated with the Packard Motor Car Co. as chief engineer and vice-president in charge of engineering, except that for about two years he was engaged in Government work in connection with the development of the Liberty aircraft engine. Mr. Vincent's work on the design of passenger cars for the Packard company had led him to make an exhaustive study of the airplane type of engine in 1915-1916 and the early part of 1917. His service in the activities involved in the design and production of the Liberty engine is well known to the members of the Society and the automotive industry. In a paper presented by him at the 1918 Annual Meeting of the Society the theory and logic of the Liberty engine program were explained, and at the 1919 Annual Meeting he gave an historical account of the development and achievement of the engine.

Mr. Vincent held a commission in the Army as lieutenant-colonel, devoting his attention to the Air Service until the latter part of 1918. He was successively in charge of the engine design section of the Equipment Division and the airplane engineering department of that Division, which had the duty of passing on designs of aircraft engines as well as on airplanes, and of the airplane engineering division of the Bureau of Aircraft Production. After the armistice he accepted a commission as colonel in the aviation section of the Signal Officers' Reserve Corps. On Jan. 1, 1919, Mr. Vincent returned to Detroit to take up his duties with the Packard Motor Car Co., as vice-president in charge of engineering.

Francis W. Davis

Councilor Davis was born at Philadelphia on Aug. 19, 1887. His first business venture was at the age of 17 when he managed a motorcycle agency and had charge of a small machine shop which specialized in repairing automobiles and motorcycles and experimental work. From 1906 to 1910 he attended Harvard University and specialized in mechanical engineering with particular reference to steam and oil engines. He was graduated in 1910 with the degree of Bachelor of Science.

Upon leaving college he entered the service of the Pierce Arrow Motor Car Co., Buffalo, and took a course in the various departments of the factory. He was then placed in the experimental department and afterward transferred to the sales department as a sales engineer. In 1915 and 1916 Mr. Davis was consulting engineer on motor trucks for the British Admiralty and War Office. In this position he had to do with the selection of the equipment, its inspection, the training of the personnel, the establishment of repair and maintenance facilities and the operation of the equipment overseas. He returned to the Pierce Arrow Motor Car Co. in 1916 as assistant chief engineer of the truck department and since that time has been truck engineer and consulting engineer of the truck department, his present position.

Mr. Davis was elected a Member of the Society in 1916. He is a member of the Truck Division of the Standards Committee, the Truck Committee of the National Automobile Chamber of Commerce, the Federal Highway Council, the Permanent Committee of Washington Highway Transportation Conference, and chairman of the Society's Committee on the Science of Truck Operation.

Glenn L. Martin

Councilor Martin was born at Maxburg, Iowa, on Jan. 17, 1886. He is one of the pioneers of aviation in America. In 1909 he began experimenting with airplanes and like many of the early flyers taught himself to fly. The following year he was a constructor and as early as 1912 he began building up a strong organization. In 1916 the company bearing his name was the principal source of airplanes for the Army and at that time held the record of having built a comparatively large number of planes for the United States Government without a single serious accident to pilot or passenger. Mr. Martin was second vice-president, representing aviation engineering, during 1920. He is president and general manager of the Glenn L. Martin Co., Cleveland.

W. A. Brush

Councilor Brush was born at Detroit, Nov. 9, 1872. He was educated in the high school of his birthplace and also pursued some independent courses of instruction. Mr. Brush has been connected with the sales department of the Packard Motor Car Co., and was formerly head of the technical department of the Buick Motor Co., Flint, Mich. Together with A. P. Brush he organized the Brush Engineering Association at Detroit, to give technical advice to motor car builders. He has been business manager of that organization since 1913.

Mr. Brush was elected to membership in the Society January, 1914, and has taken a prominent part in the affairs of the Detroit Section, having served as its chairman. He has also rendered the Society valuable service as chairman of its Membership Committee.

A. W. Scarratt

Councilor Scarratt was born in St. Paul on April 16, 1886. He received his early education in the public schools there. Later he was graduated from the Mechanic Arts High School of St. Paul after completing the engineering course. In 1905 he was employed by the Twin City Rapid Transit Co. as a draftsman in the mechanical engineering department where he was engaged in the design of car bodies and rolling stock of all kinds for approximately four and one-half years. He was then transferred to the power and electrical department, where his work consisted of powerhouse layouts and reconstruction work and sub-station design, and was later made assistant foreman at the shops of the Company. While with this Company he attended the University of Minnesota for three years.

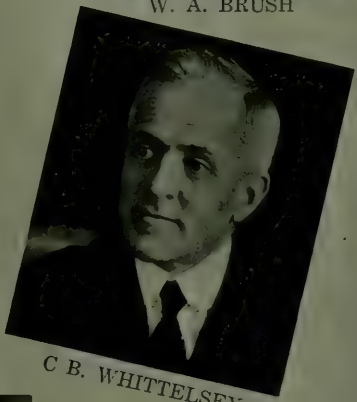
In 1913 Mr. Scarratt accepted a position in the tractor engineering department of the Minneapolis Steel & Machinery Co. He has been prominently identified with the development and production of the line of tractors built by this Company. He was elected to membership

G. L. MARTIN

F. W. DAVIS

W. A. BRUSH

COKER F. CLARKSON



C B. WHITTELSEY

F. M. GERMANE

N. B. POPE

A. W. SCARRATT

in the Society in 1915 and is at present Chairman of the Minneapolis Section.

F. M. Germane

Councilor Germane was born Dec. 13, 1873, at Chicago, Ill. He attended the public schools of that city. After leaving school he engaged in the electro-plating business, entering in 1893 the service of the George L. Thompson Mfg. Co., Chicago, in charge of several factory departments including the polishing and plating departments. When the company was absorbed by the American Bicycle Co. in 1895 all the bicycle parts manufacturing plants of this organization were segregated and incorporated as the Federal Mfg. Co. From 1898 to 1904 Mr. Germane was in the sales department of the company, having charge of the Eastern territory. He was appointed Western sales manager of the Standard Roller Bearing Co. in 1904 and after serving in that capacity for approximately two years was appointed sales manager and transferred to the factory at Philadelphia. In March, 1917, when the Standard Roller Bearing Co. was purchased by the Marlin-Rockwell Corporation Mr. Germane was made general manager of its Philadelphia and Plainville plants, and upon the formation of the Standard Steel & Bearings Co., Inc., in October, 1919, to handle the manufacture of bearings for the corporation, he was made a vice-president of the new organization.

N. B. Pope

Councilor Pope was born July 17, 1879, at Thomaston, Me. He was educated at the public schools of Kennebunkport, Me., and Cambridge, Mass., and the Lawrence Scientific School of Harvard University from which he was graduated in 1902. Upon leaving college he was employed by the Pope-Robinson Automobile Co., Hyde Park, Mass., and for a number of years was engaged with different automobile firms with which he had varied drafting-room, shop and road experience.

In 1905 Mr. Pope joined the staff of *Horseless Age* and later of *Motor World*. When the Motor Trades Publishing Co. was organized in 1911, Mr. Pope became associated with it and is now managing editor of *Automobile Topics*.

Mr. Pope was elected to membership in the Society, February, 1908, and has presented a number of papers and discussions relating to fuel questions at meetings of the Society and its Metropolitan Section. He was secretary of the Metropolitan Section for two years and a member of the Miscellaneous Division of the Standards Committee for the same length of time.

Charles B. Whittelsey

Treasurer Whittelsey has been connected with the Hartford Rubber Works Co. since 1901, beginning as its purchasing agent. In 1905 he was made assistant to the general manager, in 1906 superintendent, in 1911 secretary and factory manager, in 1915 vice-president and factory manager, and in 1916 president and factory manager. He has served as president of the Hartford Chamber of Commerce and of the Hartford County Manufacturers' Association.

Mr. Whittelsey was elected to membership in the Society in 1910. In 1916 he was elected a Life Member. He was a member of the Standards Committee for several years, beginning in 1911, and served as chairman of the Tire and Rim Division in 1918 and 1919. Mr. Whittelsey was a member of the Council in 1912 and 1913, and was elected Treasurer in 1918 and reelected each year since.

Coker F. Clarkson

Secretary and General Manager Clarkson was born at Des Moines, Iowa, in 1870, and was graduated from Phillips Exeter Academy in 1888. In 1889 he was in Government service in the Post Office Department. He was graduated from Harvard College in 1894, pursuing post graduate work there for the next two years. He was next engaged in connection with the installation of an underground telephone system in Philadelphia for two years, after which time he came to New York City and spent several years in work on technical, legal, patent, laboratory and automobile subjects. From 1905 to 1910 he was connected with the Association of Licensed Automobile Manufacturers, as secretary of its Mechanical Branch, publicity manager and assistant general manager. During this time he was the editor of the A. L. A. M. Mechanical Branch Bulletins and of the A. L. A. M. weekly digest of current technical literature.

Mr. Clarkson has been secretary and general manager since 1910 of the Society of Automobile Engineers and then of the Society of Automotive Engineers when the latter was formed.

During the war Mr. Clarkson was associated with the Council of National Defense, and served as a member of the automotive products section of the War Industries Board, and the International Aircraft Standards Board.

WAR AND COMMERCE

DURING a great military struggle energies and resources are diverted from constructive enterprise, the supplying of consumption goods and the building up of new capital. During the period of the war the people go without many things that they would like to have, and some that they need, the money going into Government bonds or their energy being devoted to war activities. Immediately following the war there is the feverish effort to catch up with the demand; people want those things that they have done without during the war. This means intense commercial activity. The immediate needs having been supplied, there comes a period of pause, usually lasting from half a year to 18 months. At the end of this pause business does not go back to antebellum figures, but usually a new era develops slowly. There was a new era for England after the Napoleonic Wars, for Germany after the Franco-Prussian War, for the United States after the Civil War, and now, at least for the United States and probably for some of our associates in the conflict, after the war just past. We can confidently look forward to a great increase in our commercial prosperity.

The United States is at the crossroad today as truly as Tyre was at the crossroad of the caravan route of Asia and the trade of the Mediterranean. We are spread out across the paths of the westerly movement in the destiny of commerce. As to natural resources and the skill of our artisans, these need no comment. Despite high wages, Yankee ingenuity and American ability to organize mass production with improved labor-saving machinery have made it possible for us, for many years, to dominate the world's commerce in such articles as harvesting machinery, sewing machines, cash registers, typewriters, office supplies, automobiles and many other kinds of goods.

The only real insurance that will spread the risks of the depression between the crests of the waves of domestic demand is the allotting of a substantial quota of a firm's product for foreign commerce and the building up in the world's markets of a selling organization and clientele that will not necessarily fluctuate with the waves of demand at home.—Director R. S. MacElwee, Bureau of Foreign and Domestic Commerce.

Presidential Address of J. G. Vincent

IN opening my address at the close of a year's tenure of office I wish first to express as forcibly as possible my appreciation of the splendid support which has been received by the officers of the Society during the past year.

Those who attended the dinner a year ago will remember that I then urged the fullest cooperation of the membership of the Society at large, stating that I realized that we had a big job before us and needed all the help we could get.

On behalf of the officers who have served during the year just closed I want to take this opportunity to acknowledge the full measure in which support and cooperation have been given. I know that I voice the sentiment of the retiring officers when I state that it has been a real pleasure to carry on the Society's affairs, partly because we realized that we were accomplishing work of national importance but more particularly because we felt that the membership at large were in sympathy with our efforts and were cooperating to the limit.

I will endeavor first to give you a general picture of the Society's activities during the past year and then point out in a brief way some of its pending problems, as well as problems of a broader nature which the automotive industry faces at this time.

Increase of Membership

The work of the membership committee under the direction of its chairman, W. A. Brush, has been continuingly effective, the average number of applications received per month during the last seven months having been approximately 90 as compared with an average of approximately 77 per month during the same period of 1919. The total number on the rolls of the Society on Jan. 1, 1921, including Affiliate Member Representatives and Enrolled Students, was 5231, constituting a net gain of 465 since June 1, 1920, after 108 had ceased to be members, owing to resignation or nonpayment of dues. This is a net gain of 715 members for the year, as compared with 651 for the previous year, which I think you will all agree represents a healthy growth, all things considered.

Section Activities

Thirty meetings have been held in this season by the 10 Sections of the Society, the subjects discussed relating not only to engineering problems of the several automotive fields within the scope of the Society's activities but also to economic trends of today. These meetings have engendered a feeling of confidence through realization of the leadership of our industry among those businesses that are vitally necessary to the world's progress. The Sections established in Boston and continued at Washington after the war period have been successful from the start. The former makes possible the affiliation in sectional activity of a large number of members of the Society resident in New England who were formerly unable to take part in this important phase of the Society affairs. The Washington Section will, it is believed, be the channel of presentation of much valuable research data resulting from the conduct of tests by various branches of the Government.

The Sections as a whole are believed to be in a healthy condition. The total number of members of the Society who hold membership in one or more Sections has increased by about 300 during the past year.

The Sections Committee, H. R. Corse, chairman, has been faithful to its duties in the conduct of the Sections.

Administrative Committees

All of our Administrative Committees have carried their work forward actively and I desire to express my appreciation of their loyal support. Much as I would like to do so, time will not permit of my enumerating the large volume of work accomplished by the various committees, but I must mention the Finance and the Meetings Committees, which have carried an extra heavy burden during the year and accomplished results of untold benefit to the Society.

Standards Work

The work of the Standards Committee under the able leadership of Chairman Bachman, is proceeding in considerable volume on many important items. The Committee is making through 12 of its Divisions, 34 recommendations at this meeting, 13 on new subjects, 17 involving revision and extension, 3 cancellations of previously accepted recommendations and 1 a special report. In June and January of the last year, 14 Divisions reported 49 and 48 recommendations respectively. The number of Standards and Recommended Practices contained in the new edition of Vol. I of the S.A.E. Handbook recently issued in rearranged form, is 210. The Committee has now in hand in various stages of progress more than 200 subjects. While a large amount of standardization has been accomplished, and many of the main features of materials and mounting dimensions of automotive apparatus have been codified, in one sense the real value of standardization is just beginning to be realized. There is no doubt that much more can be done by way of simplifying, facilitating and improving manufacture of the products with which we are specially concerned and the economical use of which in service must be fostered.

The Society is taking part in the procedure of the American Engineering Standards Committee, the first session of the Sectional Committee on Ball Bearings, organized by the American Society of Mechanical Engineers and the Society of Automotive Engineers, having been held recently and resulted in a decision to collect information as to volume and types of ball bearings made throughout the world, with a view to bringing about some international standardization. A Sectional Committee on Screw Threads has been organized in conjunction with the American Society of Mechanical Engineers, and another on Bolt, Nut and Rivet Proportions is in process of formation, as well as one on Safety Code for Aircraft, jointly with the Bureau of Standards. It is not intended that in the joint deliberation with other societies and organizations under the American Engineering Standards Committee plan, the Society shall give up any of its independence of work.

At a meeting held recently of members of the Lubricants Division and the Research Committee of the Society, a resolution was passed requesting that the United States Government Committee which, as a result of war conditions, formulates petroleum products specifications

for use in Government purchases, appoint an advisory board thereto constituted of delegates of representative associations. This action was in recognition of the fact that Government specifications, although promulgated for Government use only, have great weight in industrial practice, and the thought that industry should be consulted freely and fully in the establishment of specifications affecting it. The affirmative opinion is growing that it is feasible to establish lubricating oil specifications for general use. So far as gasoline specifications are concerned, the best view probably is that these should not be rigid but sufficiently flexible so far as periodical modification of them is concerned. The Society expects to be instrumental in demonstrating what the proper distillation curve or curves of gasoline are, with relation to ease of starting, satisfactory engine operation and economics broadly considered.

Aeronautic Handbook

The publication of the aeronautic handbook which the Society undertook something over a year ago has been delayed, owing in large part to the mounting cost of production, but it is expected that the altruistic and laudable purpose which stimulated this effort will be accomplished in some suitable manner in due course.

"Foreign Affairs" of the Society

We have been in an acute stage of overorganization for some time, nationally, industrially and professionally. In willingness and effectiveness of cooperation the Society is second to none, but there is a limit dictated by common sense to the scope of activities that can be beneficial jointly or severally. In addition to the strenuous internal activities of the Society, it has had to establish and conduct what is practically a department of foreign affairs. The Council of the Society has appointed no special committees this year except after careful consideration, to keep our methods reasonably free from complexity. There are, of course, several manufacturers' associations in our field of work with which we are naturally allied, as well as various Government Departments and Bureaus. In addition there are the following organizations with which we are cooperating or are from time to time asked to cooperate in greater or less degree:

American Engineering Standards Committee
American Petroleum Institute
Society of Lubricating Engineers
Engineering Societies Library
Engineering Foundation
National Research Council
Federated American Engineering Societies
Federal Highway Council
Motor Vehicle Conference Committee
Underwriters' Laboratories
National Safety Council
American Society for Testing Materials
National Highway Educational Conference
American Society of Agricultural Engineers
British Engineering Standards Association
National Advisory Committee for Aeronautics
National Conference on Highway Traffic
Mississippi Valley Waterways Association
International Association of Industrial Accident Boards and Commissions
Grinding Wheel Manufacturers of the United States and Canada
United States Board of Surveys and Maps

The Federated American Engineering Societies

At the December meeting of the Council it was decided not to accept at this time the invitation extended to the Society to become a charter member of the Federated American Engineering Societies. The possibilities for achievement through a national organization dealing with the non-technical activities of engineers are appreciated, and it is of course felt that the Society must accept responsibilities in keeping with position in the engineering world. Engineers are justly proud of their reputation for efficient organization. Under the industrial conditions which now exist in the United States, it is more than ever advisable that questions of economy both in money and in time be given the most serious consideration. Every new organization created must be financed and much time must be spent in the study of its proceedings, provided its work is to be made effective and really worth while. There is a tendency among some leading engineering societies toward welfare and political work in connection with the general status of the engineer as such. Much of this movement is undoubtedly justified or at any rate inevitable. We have a very large amount of work to do right in the Society which must be done. We must assist in carrying the general burden but arrange that our own immediate work shall be sacrificed as little as possible. To do the work we have in hand properly, a large amount of thorough study and attention is necessary and we have not the staff nor the income to permit much work not having a direct bearing on the promotion of the arts and sciences and standards and engineering practices connected with the design and construction of automotive apparatus and internal-combustion prime movers. Our present standing and prestige has resulted from close attention to our own matters and I believe that a properly conservative policy indicates the assumption that this will continue to be the case in practically the same degree as heretofore.

The Council and Office Staff

I wish to repeat what I said on a former occasion, that I believe that no commercial board of directors in our field is more conscientious and effective, relatively speaking, than the Council of this Society is. Before the close of my administrative year, I wish to say from actual and intimate knowledge that I am of the opinion that no office staff of a company with which are members are connected is more hardworking or competent than that of the Society. It is a striking, although perhaps natural, fact that few members of the Society really understand the nature, extent and intricacies of its work. I can testify that close contact with its affairs enhances greatly appreciation of these. The physical arrangement and departmentization of its offices were described in a recent issue of The Journal. There is not now time and this is not the occasion to itemize the activities.

When Mr. Clarkson became Secretary and General Manager of the Society 10 years ago, its office equipment was desk space in a downtown office, there were less than 400 members and he was the sole employe. Today the staff of the Society is constituted of 50 persons, we have 7500 sq. ft. of office floor space, and there are over 5000 members resident throughout the world. I shall not enlarge at all at this time on the well-known achievements of the Society, but refer to the groundwork on which they are based.

From a shoe-string treasury in 1910, the worth of the Society in quick assets including cash on hand, accounts receivable, securities and inventories, has become fully $200,000. The general reserve, constituted of unexpended income accumulated during ten years, is $130,000, or $13,000 average per year for 10 years. One indication of

the volume of business of the Society is that current incoming and outgoing first-class mail ranges from 500 to 1000 pieces per day. The Society's job is to give service to 5000 members as well as various individual and corporate non-members. It has been stated repeatedly that the standing of the Society is determined by the merit of its printed matter. The editorial work involved in the publication of papers, reports and data sheets is one of the chief burdens of the Society staff. A survey must be made of publications issued throughout the world containing automotive engineering matter of value. The conduct of the affairs of the Council alone constitutes a considerable mass of business. The meetings of the Society, particularly those termed Annual and Semi-Annual, are large undertakings. The financial affairs of the Society require considerable attention. The publication of the TRANSACTIONS, THE JOURNAL and S. A. E. HANDBOOK involves at least three separate and distinct readings of each article or document. All of these matters as well as Sections and Standards questions and considerations of policy are originated or centered at or conducted by the Society staff.

There were published in THE JOURNAL[1] diagrams showing the proportional sources of income per dollar received and proportional use per dollar expended by the Society during the last fiscal year, as well as the same information with respect to the total expense per member per year. These figures show in a clear manner the remarkable service the Society is giving the members in the form of valuable production not securable elsewhere, the cost of this being more than four times the amount of the average annual dues received by the Society from members.

PROBLEMS OF THE SOCIETY

The Society is perhaps best known for its standardization work. It has undoubtedly been most effective as well as a world-wide leader in this respect. The further work will need close attention, both as to the best system of internal procedure and in relation to national and international standardization as such. For some time the Society has been disseminating widely information with regard to its standards at a considerable financial loss and a very liberal policy in this respect should be maintained. There is probably room for improvement in the fundamental organization of the committee personnel and it is of economic importance that accurate information of a comprehensive character should be collected and collated as to the actual extent of the use of the standards, and as to the need for revision or cancellation of any of them. Likewise some suitable system should be inaugurated of listing sources of supply of products fabricated in conformity with the S. A. E. Standards and Recommended Practices. Moreover, it is not unlikely that more detailed information in connection with what standardization is contemplated should be published prior to preliminary definite action, bearing in mind that great care should be exercised in distributing advance advices to avoid misunderstanding as to their tentative nature.

The matter of the foreign relations mentioned above, that is, cooperative procedure with other organizations of this country not directly concerned with our work, will need further careful attention and handling. In addition, it should not be forgotten that international cooperation in automotive engineering standardization is probably not far off.

Some vexing questions have arisen with regard to the effect on the standardization work of claims to rights under letters patent and in connection with commercial considerations governed by competitive conditions without regard to patent rights. An instance of the latter class is the standardization of tires. At a joint meeting of the Tire and Rim and the Truck Divisions held at Cleveland in November, various other automotive vehicle designers and members and guests being present, resolutions were passed looking toward the coordinating of the effort of various organizations interested in tire and rim standardization, and the making of any necessary economic studies; and in this connection the Council has appointed a committee to report on the whole general question, with reference particularly to pneumatic tires for passenger cars and motor trucks, including limits for oversize tires, rim sections for pneumatic tires, metric tire sizes, and maximum wheel load for highways, it being understood that the various commercial considerations involved should be given particular attention. I have accepted the chairmanship of this committee and it is proposed that the National Automobile Chamber of Commerce and the Rubber Association of America shall be represented thereon.

It has been decided, after discussion of the possible activities of the Society in research work, to maintain a Research Committee. It is not considered feasible that the Society should engage in research work directly by the establishment of a laboratory or the organization of a research force. It is believed, however, that it should be ready to take up and direct from time to time certain lines of research, the duties of the committee consisting in passing on suggestions submitted to it and in deciding upon the best way of carrying out any work believed to be desirable, including the securing of financial assistance from the industry to this end.

The work on internal-combustion engine fuel that the Society has been doing will, of course, have a strong bearing on the Research Committee work. At a session held here recently attended by representatives of the American Petroleum Institute, the Bureau of Mines, the Bureau of Standards and the Society, specific recommendations for fuel tests were formulated for submission together with estimate of expense to the National Automobile Chamber of Commerce and the American Petroleum Institute with a view to starting some actual joint tests as soon as possible.

I want to stress as much as I can the importance and value of our committee work. The Society is absolutely dependent in many of its activities upon the generous assistance of experts qualified in their respective special lines of endeavor, and their proceeding together in deliberation upon the various phases and grades of problems before us spells the best form of progress in our field.

With relation to the other class of work conducted by the Society, I want to urge upon the members the need of our having for presentation at Society and Section Meetings and for publication in THE JOURNAL, professional papers of the highest possible order of merit and value. You are urged to assist the Meetings Committee as to this.

The proper balance of the so-called automotives should never be neglected in the proceedings of the Society. At this Annual Meeting there are to be presented papers and discussions having special reference to passenger cars and aircraft, as well as to the automotives in general. During the last month a Motor Boat Meeting of the Society was held, and Motor Truck and Farm Tractor

[1]See THE JOURNAL, January, 1921, p. 11.

Meetings will be held next month in Chicago and Columbus respectively.

The financial condition of the Society should be wisely conserved. While its funds, including surplus monies, are adequate for our present activities, they do not permit of any large scale operations in the way of research, for example. So far as current income with relation to expense is concerned, the Society is probably in as good a condition as any of the societies. Current income rather than surplus monies should, of course, determine budgeted current expense.

Industrial Problems

The automotive industry today finds itself facing problems of the utmost seriousness and importance. Naturally, no troubles that can arise at this time are so grave as those of the early years of the industry, when in fact the very life of the industry itself was often at stake. But in the present situation not only the growth and prosperity of the industry but to a greater extent the prosperity and development of the whole country depend upon the solution of many problems which are peculiarly within the scope of the Society.

Primarily the acuteness of immediate conditions is not due to these great problems. The industry has suffered seriously and is threatened with further suffering as a result, partly of general conditions which have affected all business, and partly of a serious misunderstanding in regard to the automotive industry which has arisen in the public mind. This misunderstanding has resulted to a considerable extent in causing the automotive industry inconvenience and distress entirely out of proportion to that suffered by other industries and entirely out of proportion to its just deserts.

There still remains in the public mind a vague belief that the passenger automobile can truthfully be called a "pleasure car"; in other words, that it is to a large extent a luxury. There even remains in the minds of many the feeling that the automotive truck is an expensive form of transportation and should be discouraged. In addition, it should be added that the rapid growth of the industry has caused a certain amount of jealousy among other men and also that the demands of the industry have furnished a convenient alibi to purveyors of steel, rubber, woolen, cotton and other materials entering into the production of automobiles when they have failed to make promised deliveries to other industries.

It is largely as a result of these misunderstandings that the automotive industry finds itself in its present condition. These beliefs, erroneous as they are, have had a decided effect upon the sentiments both of bankers and of the buying public. These sentiments are responsible for the effort now being urged before Congress to impose greatly increased taxes upon both cars and trucks.

It seems impossible that any policy so suicidal to the prosperity of the whole country, as well as one so unjust to a great industry, can be adopted. It is surprising that any argument is necessary in regard to the truck. The Government itself has records showing that the postal express lines running over distances up to 248 miles from Maryland into Washington resulted in selling farm products to consumers at something like 43 per cent less than the normal market prices. Other statistics show that truck haulage can often produce a saving over rail transportation up to distances around 200 miles. The advantages of truck transportation for shorter distances, especially in cities, have been proved by hundreds of thousands of truck owners. Even a slight investigation would show these services conclusively.

The fact that the passenger car is a factor of equal economic importance is not so easily demonstrated by statistics and this perhaps accounts for the feeling that the passenger car is a luxury, although the car passed out of that condition at least six years ago. A recent questionnaire sent out by the National Automobile Chamber of Commerce showed that 90 per cent of all passenger cars are used more or less for business purposes and that more than two-thirds of the total mileage run by passenger cars is for business. So the utmost that can be charged against the passenger car today is that it gives pleasure after it has done a full day's work. The questionnaire brought out an even more startling fact, that the average motor-car owner increases his earning capacity about 57 per cent through its use. The value to the farmer has been shown time and again and altogether no doubt can remain in the mind of any candid man who investigates that the automobile is far more than paying its own way today. In addition, of course, are the great intangible values that the automobile is giving, its contribution to comfort, pleasure and health.

Yet these prejudices have already seriously affected the automotive industry and it has been shown that they threaten its future even more seriously. Although not a problem in engineering, this condition is a matter to which members of the Society should give most careful attention and in every way possible the Society should bring home to America the very high value of the automotive industry.

While the matters affecting public opinion and Governmental action are under discussion, mention should be made of the increasing need for a Federal licensing system. The greatly increasing use of the motor truck in interstate commerce and occasionally over very long distances has made this a serious, if not vital, problem. The general practice of States of applying upon road building the fees received for automobile licenses presents some complications in the search for methods of handling the Federal licensing system, but the inconveniences caused by the present arrangements are so serious that the matter should be taken up promptly and with vigor. There is no doubt that a solution can be found that will be fair to all concerned.

The handicaps upon the industry which are peculiarly within the province of the Society and which must be solved before the automobile can render its full service to this country fall under three general heads: road construction, fuel and cost.

Roads

In the matter of roads, progress during the past year has not, in my opinion, been in proportion to the large amount of money expended on construction. Many of the roads built within the last few years of what was fondly called "permanent construction" are rapidly breaking up and too often are being replaced with roads of equal impermanence. In the meantime such roads as we have are so congested as to cause serious delays, expense and even danger to the users of both cars and trucks. While neither of these important problems comes within the direct province of the Society, they are so closely allied to our work as to make it imperative that we cooperate to the fullest extent with those organizations having the work in charge.

Studies that have been made during the past year have contributed greatly to our knowledge of the effect of vehicles on the roads. We have learned how much road surfaces can be saved by increasing the proportion of

sprung weights to those of unsprung weights in a truck. We have learned considerable regarding the amount of load that should be carried per square inch of bearing surface of tires upon the road. Care should be taken to make certain that these lessons are applied to the fullest extent in the building of vehicles and in their loading so as to lighten the task of the road engineers who are attempting to solve the problem of constructing surfaces that will withstand modern traffic.

In the matter of congestion, the assistance we can give is largely educational. It is becoming evident that the automobile is following the lines of the development of the railroad in many ways and one of these is in the sharp division into the two classes of passenger and freight traffic. The railroads, to handle their work economically, have been forced to build first two and then four tracks. It seems obvious that the automotive traffic also will eventually demand two and then four-track roads. The Society should cooperate vigorously in teaching the public the need of such roads and in working for their construction. Until they shall have been completed, we shall never be able as a nation to get from the automotive car or truck more than a small part of the service they are prepared to render us.

Fuel

The second great engineering problem which confronts the industry has to do with fuel. We have now for some years seen an increasing cost of fuel, together with decreasing quality, indicating that there is a real shortage and that the demand for gasoline has outstripped the supply, long before that demand has reached the volume that it will reach when the internal-combustion engine shall have been adapted fully to America's needs. Unless the cost of fuel can be considerably decreased and its quantity considerably enlarged, we are not far from the time when the industry will have to cease its growth with a good half of its work still undone.

The solution of this problem will need the cooperation of three parties. The oil industry itself must expand as rapidly as possible, replace antiquated refining methods with modern, and practice conservation to the limit. The public must be educated to get the maximum amount of mileage out of every gallon of gasoline. But chiefly we automotive engineers must revise and improve our designs to get every ounce of power possible out of every drop of gasoline.

Considerable steps have been made toward a solution during the past year. Most important perhaps is the understanding that has been reached between automotive engineers and the American Petroleum Institute. This should result in an intensive cooperation between the automotive industry, represented by this Society, and the oil industry, represented by the American Petroleum Institute, to the great advantage of both, as well as to the users of automotive equipment.

In the meanwhile a great volume of research and experimental work has been done and some important results have been achieved in adapting engines to use present-day fuels efficiently. This has been largely a matter of inlet-manifold design, including suitable heating means for obtaining improved vaporization and distribution of the mixture of fuel and air in the different cylinders. Considerable attention has been paid also to carburetion and thus, as a result, a somewhat improved gasoline economy has been attained. The fact remains, however, that a majority of the engines in use today are poorly equipped to handle the present grades of fuel, since they were designed several years ago. This in itself is responsible for a considerable waste of gasoline, accompanied by rapid deterioration of the engines. This condition can generally be alleviated by the use of suitable attachments for heating the manifold, and the public should be encouraged to use such devices. In general, there should be a broad campaign to teach the automobile driver how to get the utmost efficiency from his engine. I believe that this could be carried to a point where it would result in a saving of nearly 10 per cent of the gasoline now consumed.

There are a number of reasons to expect relief in the distant future from fuels other than gasoline, but the development is likely to represent a slow and tedious process. In the meanwhile we are faced with an actual situation and I can see no way of legislating increased gasoline mileage into cars or of passing laws which will compel intelligent operation by drivers. It will be necessary, therefore, to outline some definite plan of immediate procedure and, in my opinion, the most important things to be accomplished are as follows:

(1) Work out plans for the general education of operators of automotive apparatus along lines of fuel conservation using as publicity mediums:
   - *a* The service stations of the builders of automotive apparatus
   - *b* Gasoline supply stations
   - *c* Local automobile clubs
   - *d* Automotive trade journals
   - *e* Any other available means

(2) Educate the automotive engineers as to the problems confronting the oil industry and keep them posted as to the probable grades of fuel that will be available, at least two years in advance of making any change in fuel specifications

(3) Educate the engineers of the oil industry as to the problems of the automotive engineer in order that they may be fully conversant with the whole subject and be in a position to adapt the fuels to the needs of the internal-combustion engine insofar as possible

(4) Bring about thorough cooperation between the automotive industry and the oil industry and thus avoid misunderstandings and working at cross purposes which, I believe, have been common occurrences in the past

In justice to the industry, I believe it would be well to set down what the automotive manufacturers are contributing toward internal-combustion engine fuel conservation.

(1) Lighter and more efficient cars and trucks

(2) Improved efficiency of carbureters

(3) Greatly improved intake manifolding and heating devices of various sorts, all of which have for their object improved vaporization and more even distribution of the fuel to the various cylinders

(4) Improved temperature control of engines to overcome the inefficiency of cold engines

(5) Improved fuel feed systems

(6) Elimination of excessive friction in the mechanism, with consequent reduction of mechanical losses

(7) Improvements in the resiliency of tires, which alone has effected a gasoline saving of as much as 10 per cent

(8) More efficient lubricating systems and better piston fits to prevent fuel passing into the crankcase with consequent loss of gasoline and the attendant contamination of the lubricating oil

(9) Exhaustive investigations into the possibilities of increased compression, which will eventually result in an increase of at least 10 per cent in gaso-

line mileage and probably considerably more. In connection with this research work, automotive engineers had to delve into the mysteries of the molecular structures of the fuel because it is the make-up of present-day fuel alone which limits the compression, as was clearly brought out in Mr. Kettering's talk before the American Petroleum Institute

(10) Technical service divisions have been organized by the majority of automotive manufacturers to keep closely in touch with the operators of their devices and help maintain the engines and vehicles in the best possible operating condition at all times, reporting back to the factory all troubles and assisting in their cure by suggestions for improvements

Manufacturing and Operating Cost

The third engineering problem which faces the industry is that of cost in both manufacture and operation. It is obvious that we are facing a considerable period of readjustment, economy and retrenchment, and it behooves the industry to meet these conditions frankly and fully. The automotive industry has made considerable strides in the past year toward obtaining both smaller cost and smaller operating expense by the introduction of lighter cars adapted to supplement the larger heavier cars, which, however, will always be in demand by those who can afford the maximum in luxurious transportation. The fact remains that we have not begun to approach the high gasoline mileages obtained with typical light European cars. The reason for this lies in the demand of the public for cars that will go practically anywhere on high gear and have a very high rate of acceleration. Until the driving public is ready to make some concession in this direction, the automobile builder will not find it profitable to turn out cars capable of much higher mileage. The good roads movement also has an important bearing on this question. With the construction of more routes which can be comfortably negotiated with smaller cars, in contrast to the previous roads where a heavy car was essential for comfort, the use of light cars will naturally increase. So there is a direct relation between the good roads movement and automobile economy.

I have purposely confined my discussion of these problems to a consideration of their bearing on the car and truck branches of the automotive industry, because I do not feel qualified to discuss in detail their possible affect on the tractor, marine engine, and farm power divisions. It is safe to state, however, that these newer branches of the automotive industry are vitally interested in the fuel problem and improved general efficiency as well as reduced cost. Although I realize that this discussion has become rather lengthy, I do not feel justified in bringing it to a close without touching briefly on the aircraft situation, as I think that this is particularly a matter of national importance and one which, therefore, should have our most loyal support.

Aircraft

Aircraft development during the past year has followed along rational lines on a scale commensurate with the service which present-day aircraft are able to furnish. The airplane has not leaped into the commercial popularity which some of its ardent and perhaps over-optimistic supporters believe is warranted, nor on the other hand has the industry gone entirely to the "bow wows," as some of our calamity howlers would lead us to believe. The airplane is being developed by arduous labor and concentrated effort which must ultimately result in aircraft playing an important role in passenger, mail and express transportation. We must bear in mind that the extraordinarily rapid development of the airplane during the war was due primarily to the service which it alone could render. In peace time, however, aircraft transportation is in direct competition with the older transportation methods. At present, its field is confined to those special cases where the tremendous speed or the ability to fly direct between two points, perhaps inaccessible by other means of locomotion, or at best by tortuous routes, or perhaps necessitating the change from railroad to steamship and back to railroad, are the influences resulting in the choice of aircraft transportation.

The last year has seen the development and extension of typical services for which airplanes are well fitted in their present stage of development. The steady expansion of the air mail service should be a source of intense national pride, this being by far the most ambitious undertaking of its kind in the world. During the past year the air mail service has been extended from coast to coast with numerous connecting lines in operation or planned for the immediate future. We should see that appropriations are ungrudgingly made for the further development of the air mail, for not only is business already reaping the benefit accruing from the faster means of communication, but this service, as I have frequently pointed out, forms an invaluable source of personnel and materiel available in a national emergency. Furthermore, I know of no better stimulus for the growth of commercial aviation than the splendid records now being made for reliability and reasonably low cost of operation by our postal air service.

For sheer audacity and courageous execution, I can think of no better example than the famous Alaskan flight undertaken so successfully by the Army. This afforded a wonderful demonstration of present-day reliability of engines and planes, as well as reflected superb efficiency and endurance on the part of the personnel. It must be borne in mind that any forced landing anywhere over hundreds of miles of the difficult territory covered in this flight would have been disastrous if not fatal. There were not any radical improvements in these planes or engines, but the details of construction and installation had been carefully worked out and the crew were specially picked for their knowledge and experience.

The Key West-Havana Service has had an auspicious start and will doubtless attain the same popularity as has been accorded the British and French Cross-Channel Service.

The Navy has prosecuted important development work with the limited funds available and at the present time the Naval Air Service is conducting joint maneuvers with the fleet on a larger scale than heretofore attempted. The Army Air Service has likewise been extremely active in research work and has accomplished many detail improvements, as well as arrived at satisfactory types of planes for the various kinds of war service.

Summing up, it is evident that the past year has seen a steady improvement in the reliability of the airplane, an extension in the use of aircraft where this was justified by the inherent advantages of this system of transportation, and attainment in the field of research limited alone by the funds available. We can look forward to greater accomplishments in the coming year, provided adequate appropriations are secured. Design tendencies in general will include a greater attention to details of

(*Concluded on page* 162)

Fuel Problem in Relation to Engineering Viewpoint

By A. L. Nelson[1]

Annual Meeting Paper *Illustrated with* Photographs and Drawings

It is believed that never before in the history of the Society of Automotive Engineers has a single problem been so universally studied as the fuel problem which is confronting us today. It also is believed that never before have we had a problem which includes such a wide scope of work. The solution calls for the service of every class of engineer, inventor and scientist. It is most gratifying to realize the large amount of ingenious research that is giving us day by day a broader view of the problem. When we have worked out the proper viewpoint and thoroughly understand our problem, the eventual solution should follow with relative ease. It is on this ground that particular emphasis is laid on the engineering viewpoint for, obviously, this will have a large bearing on keeping our efforts going in the right direction.

This paper does not attempt to give highly scientific information, the correlation of the last word in test data or to claim the solution of even the merest detail of the fuel problem; its real object is to appeal for a broader viewpoint and give a few illustrations and tests which show that the solution of a problem may lie in an entirely different method than that which often becomes stereotyped by sheer usage, rather than by its specific merit. The American engineer is too ingenious, too susceptible to practical new viewpoints to follow an old beaten path in only one direction, unless it follows from being off-guard and letting it become a habit. In the solution of the fuel problem we undoubtedly will have to change some of our old habits, replacing them by studiously worked out viewpoints. The illustrations given will clarify what is meant and will, together with the tests, serve to give a quantitative analysis of the merits of the results obtained by the changes in viewpoint. The further object of this paper is to seek the correlation of the experience of the entire engineering fraternity, to obtain their comments and seek their suggestions. It is hoped that the discussion following the reading of this paper will bring out much valuable information and materially expand our viewpoint of the fuel problem.

Recognition of Cooperation and Assistance

The eventual solution of the fuel problem will likely be the correlation of the proper solution of the almost innumerable details. We cannot, therefore, help but applaud the successful efforts of men whose work has earned our highest esteem, nor can we help but applaud those that are succeeding to a lesser degree. That this paper might be of interest to as large a number as possible a preliminary paper was submitted to representative engineers asking for suggestions, criticism and any comments which would help make the final paper a cooperative one. The generous response was very helpful indeed. The sincerest thanks and the assurance that the help is highly appreciated are extended. Many of the suggestions offered are indeed worthy of separate papers and, therefore, it is impossible to incorporate them in this. As a case in point, the importance of turbulence will not be mentioned, but it is hoped that the discussion following the reading of this paper will cover the matter as fully as possible.

As a matter of an expression of gratitude to those whose help has been most liberal the following names are mentioned. I am particularly indebted to C. S. Crawford, Harold Nutt, J. G. Vincent, H. L. Horning, H. M. Crane, C. F. Kettering, C. F. Johnson, E. A. De Waters, C. R. Richards, C. P. Grimes, Thomas Midgley, Jr., Frank Johnson and others; also to the members of the engineering department of the Premier Motor Corporation for their assistance in the preparation of the paper.

Some remarks will be made later which it is hoped will not be misconstrued. They refer to faults in regard to which the most exacting engineers cannot be justly accused and will not apply to them. However, if we are to be frank with ourselves, the remarks will apply to all of us to at least a small degree without being looked upon as non-constructive criticism. However well the specialist may know his particular subject, if he is presented with an entirely different viewpoint of some specific problem, the aspect of the problem may be entirely changed. This may lead to an easier solution than that obtained without the change in viewpoint. We are all familiar with the cleverness with which the scientists have worked into the very heart of natural sciences.

For instance, in mathematics, there are clever tricks making possible the easy solution of certain types of differential equation. These are nothing more or less than simple inventions that would have hindered the progress of mathematics had they not been discovered. It is thought that discoveries of analogous schemes will have a large bearing on the eventual solution of the fuel problem. When we compare the present stage of our problem with the highly developed stage of the natural sciences, it is thought that all of us will willingly open our minds fully to the possibilities of changes in viewpoint.

Let us consider how we often discuss some of our problems affecting the fuel situation, without the important specific correlation of engine and chassis data. We know off-hand the general engine characteristics at full, three-quarter, one-half, and one-quarter load. We know the power, friction losses, economy and the like. This is all very proper and applies very well to what the engine *can do*, but how about the more important questions of engine characteristics while working at loads that it is *called upon to do* in the car? How much specific information can we give off-hand on these more important engine characteristics so vital to the solution of the fuel problem?

[1]M. S. A. E.—Chief engineer, Premier Motor Corporation, Indianapolis.

TABLE 1—CAR CHARACTERISTICS FOR CONSTANT SPEED

Car Speed, m.p.h.	Power Required of Engine, b. hp.	Rear-Axle Gear-Ratio						Constant To Be Multiplied by the Ounces of Gasoline Consumed in 2 Min. To Get the Fuel Consumption in Pounds per Brake Horsepower per Hour	Constant To Be Divided by the Ounces of Gasoline Consumed in 2 Min. To Get the Miles per Gallon[2]
		4.5 to 1		3.5 to 1		2.5 to 1			
		Engine Speed, r.p.m.	Engine Pull at 15.756-In. Arm, lb-in.	Engine Speed, r.p.m.	Engine Pull at 15.756-In. Arm, lb-in.	Engine Speed, r.p.m.	Engine Pull at 15.756-In. Arm, lb-in.		
10	2.40	450	21.3	350	27.4	250	38.4	0.7820	32.27
15	3.75	675	22.2	525	28.6	375	40.0	0.5000	48.40
20	5.20	900	23.1	700	29.7	500	41.6	0.3610	64.53
25	7.00	1,125	24.9	875	32.0	625	44.8	0.2680	80.67
30	9.10	1,350	27.0	1,050	34.7	750	48.5	0.2060	96.80
35	11.50	1,575	29.2	1,225	37.6	875	52.6	0.1630	112.90
40	15.10	1,800	33.6	1,400	43.1	1,000	60.4	0.1240	129.10
45	20.10	2,025	39.7	1,575	51.0	1,125	71.5	0.0933	145.20
50	27.60	2,250	49.1	1,750	63.1	1,250	88.4	0.0680	161.30
55	36.50	2,475	59.0	1,925	75.9	1,375	106.2	0.0514	177.50
60	46.20	2,700	68.5	2,100	88.0	1,500	123.2	0.0406	193.60

[2]The weight of 1 gal. of gasoline is taken as 96.8 oz.

DATA RELATING TO TABLE

Outdoor Temperature (average) deg. fahr.	76
Barometer (average) in. of mercury	30.15
Weight of Car with Fuel and Two Spare Tires, lb.	4,340
Weight of Driver, lb.	180
Total Weight of Car and Driver, lb.	4,520
Tires	Firestone Cord
Size of Tires, in.	33 x 5
Air Pressure, Rear Tires, lb. per sq. in.	50
Air Pressure, Front Tires, lb. per sq. in.	45
Course	Indianapolis Speedway
Pavement	Brick
Length of Course, miles	½
Direction of Driving	North and South
Roll of Right Rear Wheels per Turn, in.	106.25
Roll of Left Rear Wheels per Turn, in.	105.00
Average Roll of Rear Wheels per Turn, in.	105.62
Number of Turns per Mile	600
Exhaust Cutout	Open
Oil	Mobiloil B

We know the general bearing in a vague way that the chassis weight, rear-axle gear-ratios, engine size, piston compression ratios and similar factors have on the fuel economy. The more complicated cases of rapidly changing driving conditions are little understood in a specific way. Are we not even weak on the conditions obtaining at constant-speed driving, apparently for no other reason than our *habit* of neglecting to investigate this important matter? This investigation can be made readily after determining the power required to drive the car at constant speeds.

ENGINE POWER REQUIRED TO DRIVE THE CAR AT CONSTANT SPEED

In relation to car speed, Fig. 1 shows the engine brake horsepower required to drive one of our American cars of the large-car class. The figure also shows the brake horsepower available and the percentage of the available power used at each speed. Table 1 gives the data relative to car weight, tires and course. It also gives the brake horsepower required for car speeds from 10 to 60 m.p.h., together with the engine speed and torque for rear-axle gear-ratios of 4.5 to 1, 3.5 to 1 and 2.5 to 1. The constants given in the last two columns are used when running engine tests on the dynamometer to compute the gasoline consumption in terms of pounds per brake horsepower per hour and miles per gallon.

The method of obtaining these data is to drive the car on a given course at constant car speeds corresponding with a fixed carbureter throttle setting, then to remove the engine from the car to the dynamometer stand to determine the power at those settings and the engine speed corresponding to the car speeds. It is necessary to duplicate very accurately the fixed throttle settings when the engine is put on the dynamometer; therefore, a micrometer adjusting screw was attached to the carbureter throttle-shaft mechanism, always using full turns only and then measuring from the locking nut to a fixed line on the screw as a means of recording the setting. The speed of the car was obtained by timing with a stop-watch on a ½-mile measured course, driving in both directions for each setting to eliminate the wind resistance by taking the average speed. The engine speed is obtained by noting the roll of the rear tires per turn and with the car speed and rear-axle gear-ratio, the number of revolutions per minute is calculated.

The average result of the dynamometer tests is

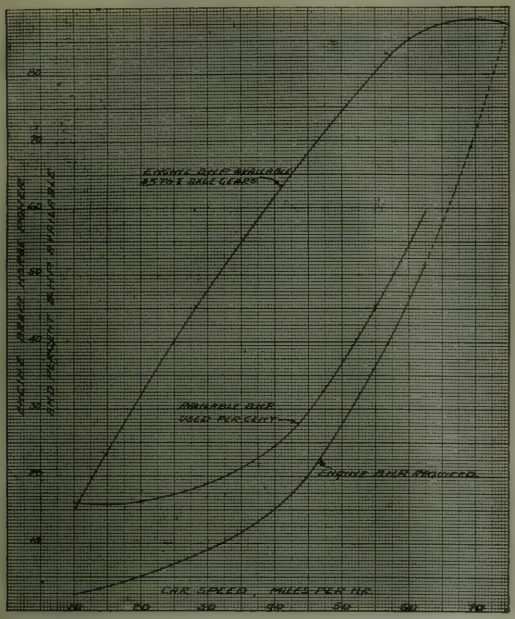


FIG. 1—ENGINE POWER REQUIRED AT CONSTANT CAR SPEED

plotted and the results of the smooth curve drawn through these points are given in Table 1. Several important details, such as cooling water temperatures, oil temperatures, air pressure under the engine hood, and the like, need not be given here. However, it is suggested for accurate work that, in addition to the use of fixed throttle settings, manometer readings be taken of the intake-manifold depression together with the air temperature. The method of keeping the water circulation the same on the dynamometer as in the car will be given in describing the equipment used in the engine tests to follow. Referring again to Fig. 1, note that the usual engine characteristics of even one-quarter load do not apply below 40 m.p.h. At average driving speed the engine is only working at 16 to 19 per cent of full load.

By means of the data given in Table 1, which states the standardized power requirements of this particular model of car, we can analyze readily the engine characteristics by running tests on the dynamometer. It is obvious to expect that poor economy is caused by misapplication of the engine rather than poor engine economy. The analysis should give us relative values on which to consider the feasibility of using two-speed rear-axles, more speeds in the transmission, or perhaps an entirely new and better way will be devised eventually to keep the load factor of the engine high to obtain better economy. Tests will be given further on giving quantitative analysis of the conditions existing.

The conditions revealed by the correlation of engine and car characteristics are so bad that both the public and engineers need a decided change in viewpoint; the public in what they demand, and the engineer in what to furnish and in what to educate the public to expect. Some illustrations will be given next to demonstrate results following from a change in engineering viewpoint.

HIGHER PISTON COMPRESSION RATIOS

As an illustration of remodeling our viewpoint, let us consider the effect of using higher piston compression ratios. We all know that the compression ratios, as used in aviation engines, give us much higher fuel economy than those used ordinarily in automobile engines. Then why not use high compression ratios for automobile engines? We are told that higher compressions make the engine knock badly. Experience tells us that the simplest way generally accepted for getting rid of the knocking is to lower the compression ratio. The point is, shall we accept this way as final? Why not try to accomplish the same result some other way and at the same time maintain the higher economy?

We all know that an engine at full load may knock badly at 500 r.p.m. and that perhaps it will not knock at all at 1200 r.p.m. If we study the curve of brake mean effective pressure, we will find that, at 500 r.p.m., the brake mean effective pressure is greater than at 1200 r.p.m. Fig. 2, curve *B*, illustrates this. By lowering the compression to eliminate the knock, we obtain curve *A*. Suppose we go back to the higher piston compression ratio and at the same time we delay the inlet-valve timing. Experiments show that we get a brake mean effective pressure similar to curve *C*, the peak of the curve coming at a higher speed than that given by the conventional timing. The pressures at the lower speeds are reduced, which is the desired result to overcome the knocking, while the pressures at the higher speeds are materially increased.

The exact timing to use depends on the valve sizes, intake passages, carbureter characteristics and similar factors. The results obtained are more far-reaching than merely keeping the pressures within a range to eliminate the knocking at the lower speeds, and increasing the power at higher speeds. The most desirable re-

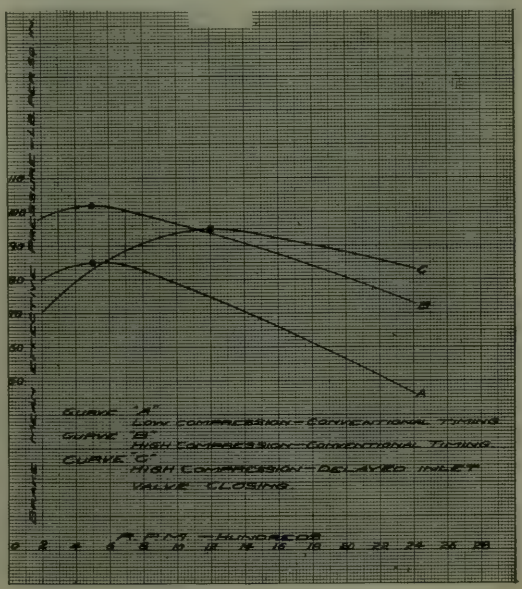

CURVE "A" LOW COMPRESSION—CONVENTIONAL TIMING
CURVE "B" HIGH COMPRESSION—CONVENTIONAL TIMING
CURVE "C" HIGH COMPRESSION—DELAYED INLET VALVE CLOSING
R.P.M.—HUNDREDS

FIG. 2—COMPARISON OF GENERAL BRAKE MEAN EFFECTIVE PRESSURE CURVES

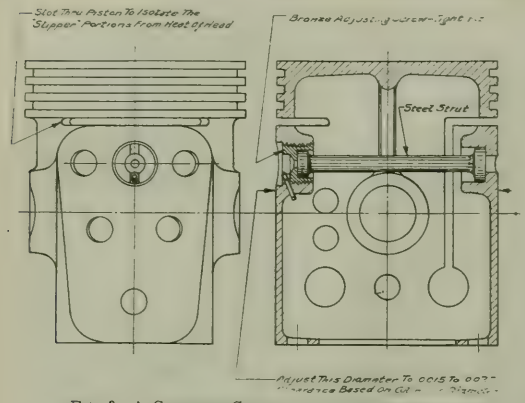


FIG. 3—A CONSTANT-CLEARANCE ALUMINUM PISTON

sults are obtained under car-driving conditions. The small charge of mixture required is taken into the cylinder and compressed to a smaller volume than in the case of the lower compression; also the charge is purer, due to the better scavenging of the higher compression pistons. The comparative tests given further on for 5 to 1 and 4.25 to 1 compression pistons at full load show increases of 13 and 24 per cent in the brake thermal efficiencies at 700 and 2100 r.p.m. respectively; while at these same speeds and at loads required by the car the increases are 22 and 41 per cent respectively. (See Figs. 29 and 30, on page 114, at 20 and 60 m.p.h. respectively.) These results are representative of only the first attempt, yet they are quite appreciable gains in economy and are due solely to the change in viewpoint on compression ratios.

CONSTANT-CLEARANCE ALUMINUM PISTON

Suppose we consider the aluminum piston, which is almost universally used in aviation engines. The high thermal conductivity of aluminum allows the heat to flow from the pistons more freely than from any other metal commonly used, contributing highly to the best known results obtained from high-speed internal-combustion engines. Why are the aluminum pistons for automobiles, though largely used, condemned by some of our leading designers of national reputation? They know the sterling qualities of the aluminum aviation pistons that make the high power and economy of aviation engines possible, yet for their automobile engines they use cast iron which perhaps could not possibly be used in the aviation engines with the high compression ratios. They tell us the trouble is that the aluminum pistons expand so much when heated that they require excessive cylinder clearance and that this allows them to slap at the lower speeds, or, if fitted closer, to stick at the higher speeds. As an alternative they select cast-iron pistons with lower compression and lower economy and greater torsional vibration of the crankshaft due to the heavier reciprocating parts and occasionally scoring the cylinder blocks. Some engineers feel, in addition, that the hotter cast-iron piston helps to vaporize the liquid fuel that comes in contact with the head of the piston.

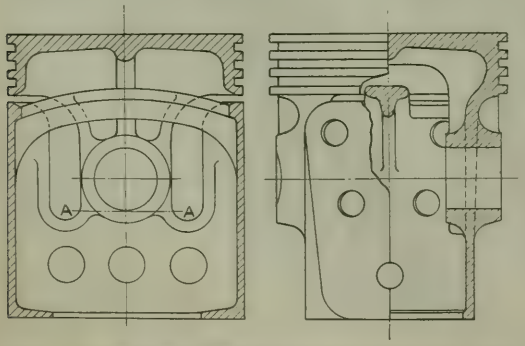


FIG. 4—ANOTHER TYPE OF CONSTANT-CLEARANCE PISTON WHICH HAS A STEEL STRUT CAST INTEGRALLY WITH THE SLIPPER PORTION

The specific heat of aluminum is greater than that of iron, but the density of iron compared with that of aluminum gives us a heat capacity per unit volume of aluminum as being 68 per cent that of iron. This is 32 per cent in favor of the iron. However, the conductivity of aluminum is 2.85 times that of iron. From these figures it will be seen that even if the iron piston was 1½ times as hot as the aluminum piston, the heat flow to the liquid fuel in contact with the aluminum piston-head would be about 30 per cent greater, and for same temperatures the heat flow would be about 94 per cent in favor of the aluminum. Since the aluminum piston-head usually is made thicker than that of cast iron, the amount of heat available would be approximately the same in both cases. From the foregoing it appears that the two pistons are on a par, except that heat flow is greatly in favor of the aluminum piston. The thing that seems to keep these engineers from changing their viewpoint is that it has become a habit to think that aluminum pistons must expand. Why not design an aluminum piston that cannot expand as far as cylinder clearance is concerned? This viewpoint changed the complexion of the whole problem and led to the development of aluminum automobile piston design that gives results thought to be in advance of the combined merits of the aviation piston and the cast-iron piston.

This piston is illustrated in Fig. 3. In this design the adjustable *steel* strut controls the cylinder clearance in the direction which prevents piston slap. It will be noted that the *aluminum* has nothing to do with the cylinder clearance. The strut is subject to almost the same temperature range as the cylinder; hence, the clearance remains constant through the range from a stone-cold to a steaming-hot engine. This type of piston proved very successful from the outset. It is the only type of piston, regardless of material or design, that we have not been able to make stick under abnormal conditions. It has absolutely no slapping tendencies even for a stone-cold engine. Maximum speed can be maintained on the Speedway indefinitely without causing the pistons to stick. For a more severe test the pistons were run at full load for 30 min. at 3000 r.p.m., with the radiator cooling water shut off so that the engine steamed continuously during the run (See Fig. 17 on page 109). This run was made at the end of a full day of high-speed testing with no provision for cooling the oil. The cylinder clearances of the pistons were less than those of any cast-iron pistons that we know are used in quantity production. Two of the pistons had cylinder clearances of 0.0015 in., based on the diameter. The other four pistons had clearances from 0.0020 to 0.0025 in.

In spite of all the abuse we have been able to impose on this type of piston, the pistons have always come out of the tests entirely free from any scoring marks and

show a decided general tendency to polish-up smoother than the conventional aluminum piston. This undoubtedly follows from the maintenance of the proper clearance at all times, thus avoiding excessive bearing loading. Another striking characteristic of the pistons is their smoothness of operation, showing that even when the slap in the conventional piston is not audible there is a rumbling sound which becomes noticeable when compared with the operation of the constant-clearance piston. This difference is very marked at both high and low speeds. When the pistons are used with the conventional timing, the knock at full load and low speeds is very materially subdued compared to the conventional type of piston. This clearly shows that cylinder piston clearance has much to do with the degree of audibility of the knock.

Fig. 4 illustrates a design which has the strut cast integrally with the "slipper" portion of the piston, the latter being well insulated from the heat of the piston-head by being separated from it. The side-thrust of the piston-pin being carried by the cantilever action at section *AA*. An alternative of this design is a steel strut cast in place or fastened in some suitable manner.

Fig. 5 illustrates an aluminum piston that *contracts* when heated, so far as cylinder clearance is concerned. The steel struts in this case are shown cast in place. The reason the cylinder clearance increases with the heat on the piston is that the ends of the steel struts attached to the piston-ring-groove portion of the piston-head are carried outward, drawing the "slipper" portion inward since they are attached to the opposite ends of the struts. A large variety of designs can be made embodying the strut idea to accomplish variations of cylinder clearance, adjustment and the like, as may be desired for particular cases. It is hoped that these piston illustrations will fix the idea firmly that, so far as cylinder clearance is concerned, we have nothing to fear from the highly expansive aluminum as a piston material. As for the practical merits of the constant-clearance type of piston, they must be tried to be appreciated, because the results they give are so far in advance of one's highest expectations. The results are indeed a striking illustration of what can be accomplished by a mere change in viewpoint.

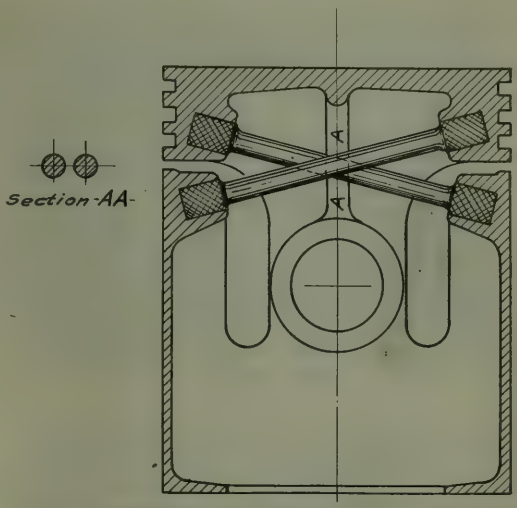


FIG. 5—A VARIABLE-CLEARANCE ALUMINUM PISTON IN WHICH THE CYLINDER CLEARANCE INCREASES AS THE PISTON BECOMES HEATED

FUEL VAPORIZER

Consider the general experience on exhaust-heated intake-manifolds. It is generally agreed that the results are fairly good, at the expense of a loss of maximum power due to unduly heating the air. On heating the fuel by "hot-spots," the air is also heated. The experience has been so general that it has practically fixed in our minds as an irrevocable fact that using exhaust heat necessarily must unduly heat the air. To show that this is not the fact, first let some suppositions be given which can be agreed to readily.

Suppose we run all the hot exhaust gases through a jacketed intake pipe, say some 10 in. long, to get ample surface for the "hot-spot;" that is, ample surface to transmit the exhaust heat required to vaporize the fuel, which, it has been observed, goes to the walls of the intake pipe or points of lowest air velocity. Such an intake pipe works well but it also heats the air along this surface, which is of low velocity, coming into contact with the large highly heated surface with the result that the maximum power cannot be obtained. At this point, suppose the old viewpoint of necessarily heating the air be discarded. Let us corrugate the intake-pipe surface so that the air passage is say 2½ in. long, without reducing the area of the inner or outer surface. As a practical means, materially increase the inside diameter of the intake pipe at this point and cast circular ribs on both the inner and outside surfaces. To make this clear, Fig. 6 shows a cross-section of such an intake pipe designed for the 295.2-cu. in. six-cylinder engine used in the tests to follow. Note the relatively small amount of surface exposed to the exterior of the heating chamber, which is an important item for starting out with a cold engine, and the efficient heating of the pipe at low car speeds. The heated portion of the pipe is set at an angle above the carbureter so as to

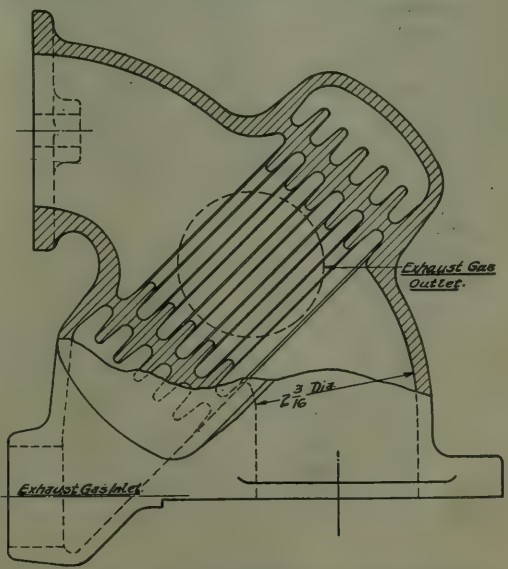


FIG. 6—CROSS-SECTION OF INTAKE-PIPE FUEL VAPORIZER USED IN THE TESTS

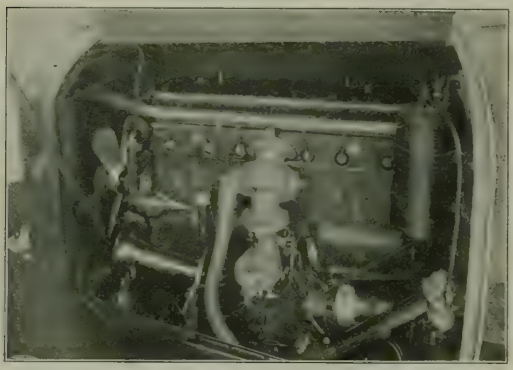


FIG. 7—THE CARBURETER SIDE OF THE ENGINE IN PLACE IN THE CAR

take advantage of the inertia of the fuel globules that may be thrown directly into the large highly heated surface. This also puts a bend into the pipe to bring the flow of liquid following the wall to the inner or smaller radius of the bend. Gravity helps to get a flow of the liquid over the heated surface. It cannot get out again into the air-stream before being highly vaporized.

The liquid fuel, while in the air-stream, seeks the walls of the pipe, as before mentioned. The highly heated corrugated surface effectively traps the fuel and quickly vaporizes and "super-heats" the vapor. Tests indicate that the air is very slightly heated while the fuel is highly vaporized. Kerosene is vaporized as readily as gasoline, even at speeds as low as 200 r.p.m. with wide-open throttle. The reason the air is slightly heated follows from the fact that only a very small portion of the air comes in contact with the edges of the ribs at the inner diameter. The actual length of the exhaust-heated intake-pipe is only $\frac{5}{8}$ in. so far as the air is concerned. Tests have been run, *abnormally* heating the intake-pipe, with only a loss of 1.2 per cent of the power at 1200 r.p.m. and 2 per cent loss of power at 2400 r.p.m., compared with the best results that could be obtained from the most favorable degree of heat and unheated plain manifolds. The design as shown does not strictly confine the heat to the ribbed portion for practical reasons. If the heated portion were isolated, undoubtedly better results could be obtained as far as maximum power is concerned when using an excessive amount of heat.

The operation of the intake pipe in connection with the remainder of the intake passages to the cylinders has some peculiar characteristics that are very important. Off-hand it would appear as though the deep ribbing would offer a severe obstruction to the fuel passing to the cylinders. Let us compare what happens with that of the ordinary manifold where the fuel as a rule travels very much slower than the air-stream flowing along the manifold walls. A considerable time interval obtains between the time the fuel leaves the carbureter nozzle and its reaching the cylinder. In the case of the intake pipe, Fig 6, and the remaining passages to the cylinder, the heavier parts of the fuel are momentarily arrested, but they are highly vaporized quickly and pass to the cylinder at the same speed as the air-stream. Since a highly heated surface can be used without heating the air, the vapor becomes heated to a point high enough so that it does not condense while in the air-stream. Of course, the vapor going into the air-stream receives a high velocity on the outset, and the time interval for it to condense is small. Practical driving tests with and without accelerating devices verify the above explanation.

Most convincing observations are made when applying 2-in. carbureters to the engine, both on the dynamometer and on the road. For speeds below 800 r.p.m. with open throttle, the unheated plain intake-pipe could not be used at all. Even at higher speeds the economy was poor although the power was good, showing poor distribution. With the new-design intake-pipe the engine could be run to as low as 200 r.p.m. with wide-open throttle. However, this does not apply to 2-in. plain-tube carbureters that we have tried without making structural modifications in the design.

In connection with the exhaust heating of the special intake-pipe, it made it possible to equip the engine with a 2-in. carbureter. The car accelerates well in cold weather, without pulling the choker, by the time it can be driven out of a cold garage onto the street. A valve, manually operated, forces all the exhaust heat through the intake. This is used until the engine heats to the normal operating temperature, or it can be left on continuously without causing any harm except a slight restricted exhaust passage for high speed in this particular experimental design. The good acceleration while cold indicates the "super-heating" of the fuel; in other words, it does not condense materially before reaching the cylinders, even when the engine is cold. With the larger carbureter and its corresponding higher power at both low and high speeds, there also obtains a smoothness that never was obtained with smaller carbureters. The degree of flexibility, smoothness, economy and power are far in advance of the best previous results. The engine shows good torque, right down to the point of stalling. It is believed that even these preliminary investigations show that the conventional hot-spot method can be far surpassed and that the fuel can be heated without unduly heating the air. The results obtained are directly responsible to the change in viewpoint.

We will next consider tests showing the application of the correlation of car and engine characteristics using 4.25 to 1 and 5 to 1 compression pistons in the same engine. First a brief description of the basic principles of the engine and testing apparatus will be given.

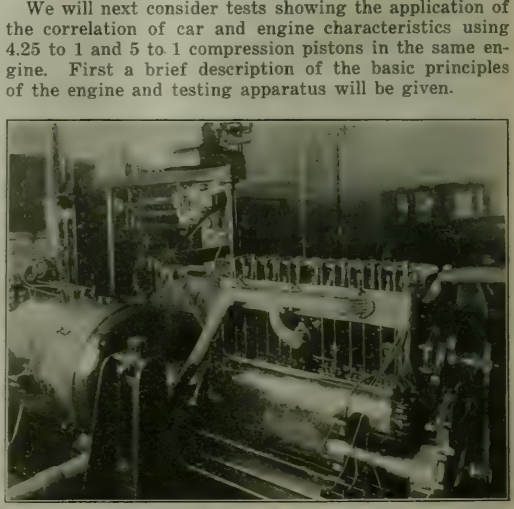


FIG. 8—THE EXHAUST SIDE OF THE ENGINE

Basic Principles of the Engine

It will be of interest to emphasize some of the high lights of the engineering principles of the engine and give data that may be helpful to those that might wish to go further into details. It is a valve-in-head, six-cylinder, 3⅜ x 5½-in. engine of 295.2-cu. in. displacement. The cylinder block and upper crankcase is a one-piece casting of aluminum alloy, with inserted cylinder sleeves of cast iron machined all over. The cylinder-head is of cast iron and detachable. Fig. 7 shows the general appearance of the engine as installed in the car. Fig. 8 shows the opposite side of the engine with the side cover-plate and valve-cover removed. Fig. 9 shows a cross-section of the engine which gives a fairly good idea

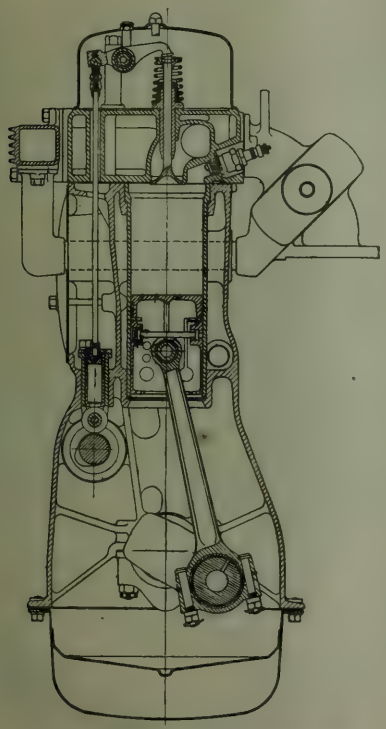


Fig. 9—Cross-Section of the Engine

of the detailed construction. The crankshaft is of the three-bearing type and of liberal dimensions. The hollow crankpins are 2¼ in. in diameter and 1¾ in. long. The shaft is drilled for oil passage at 25-lb. per sq. in. pressure to all the main and connecting-rod bearings.

Attention is called to the unique cylinder-sleeve construction with particular reference to the application of the packing at the bottom of the sleeve. The sleeve at the bottom diameter has a snug slip fit in the aluminum case. The sleeve, however, has been shown to have a very slight axial movement here. This follows from the fact that the aluminum case is not subject to as high a temperature range as the cast-iron sleeve, the higher coefficient of expansion of the aluminum being offset by

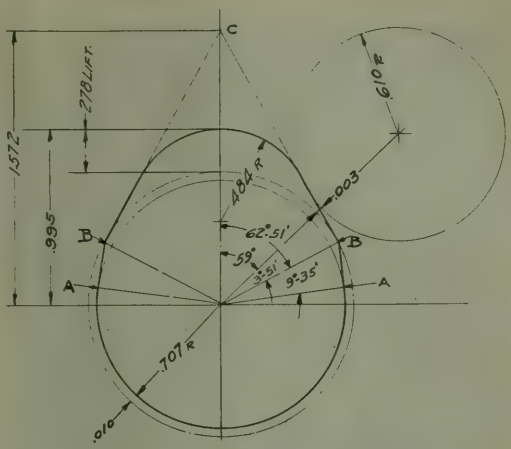


Fig. 10—Details of the Inlet and Exhaust Cams

The Exhaust Cam Leads the Inlet by 118 Deg. *AB* and *BC* Are Straight Lines Intersecting at a Sharp Angle at *B*

the greater temperature range of the sleeve. The pressure on the combination cork and hydroil packing is in an axial direction only; that is, there are no radial components of pressure from the reactions of the packing to throw the sleeve out of round. This is the characteristic difference from other types of sleeve constructions and is the basic principle making the installation of a sleeve construction successful.

Fig. 10 gives the details of the inlet and exhaust cams, both cams being identical. Fig. 11 gives the flywheel timing diagram for a valve-stem end-clearance of 0.0212 in.; however, the operating valve-stem clearance is 0.015 to 0.017 in. This is a special type of cam having a zero opening and closing valve velocity regardless of engine speed. A detailed description and mathematical analysis of this type of cam will be found in the 1917 S. A. E. Transactions, Part 1, pages 328 to 337. Fig. 12 on page 108 gives the valve-mechanism characteristic curves for an engine speed of 3000 r.p.m. Attention is called to the design to obtain a high acceleration away from the cam and a low acceleration toward the cam; that is, the acceleration that must be produced by the valve spring to keep the

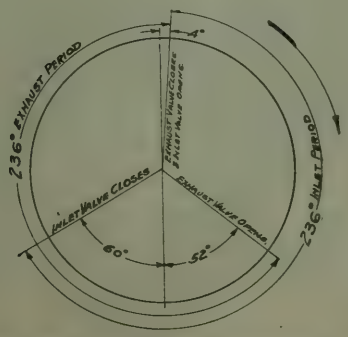


Fig. 11—Flywheel Timing Diagram for Checking Assembly of Camshaft in Engine

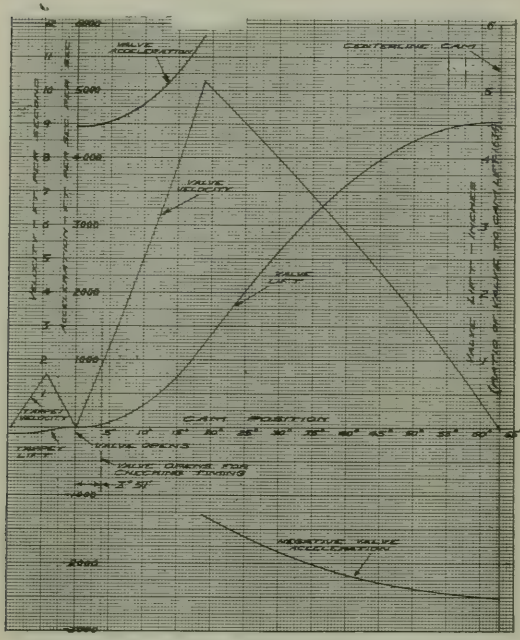


FIG. 12—VALVE-MECHANISM CHARACTERISTIC CURVES AT AN ENGINE SPEED OF 3000 R.P.M.

roller following the round peak of the cam, the 0.484 *R* shown in Fig. 10 on page 107. The equivalent weight of all the accelerated parts considered placed at the valve is 0.7635 lb. The valve-spring pressure required at 3000 r.p.m. is 59.8 lb. per sq. in.; at 3200 r.p.m. it is 68 lb. per

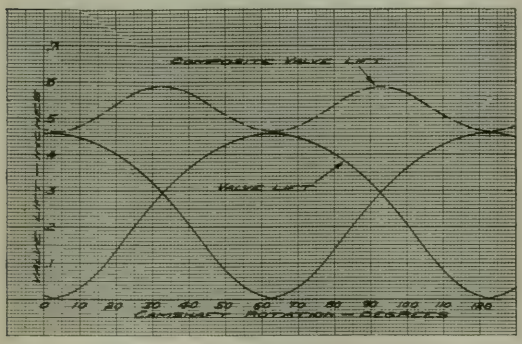


FIG. 13—THE INLET-VALVE TIMING OVERLAP

sq. in.; at 3400 r.p.m. it is 76.8 lb. per sq. in. Great care is taken to have the master cam ground to a true radius at the peak of the cam. If the cam generated has any bumps on the peak radius, it is impossible to obtain high-speed operation for two reasons. The irregularities set up synchronous vibrations in the valve springs and the accelerations are immensely increased, making the springs too weak. For instance, if the 0.484-in. peak-radius has waves on it of 3/16-in. radius, the acceleration is increased 116 per cent. These points are mentioned because they are absolutely vital to the successful application of the valve mechanism of the roller type to a valve-in-head engine operated at high speeds.

Fig. 13 gives the inlet-valve timing overlap. This diagram shows that although the inlet-valve is held open fairly late, the valve of another cylinder is close to its maximum lift, preventing a blow-back into the carbureter.

Fig. 14 shows a diagram of the intake-manifold passages. These are cast within the cylinder-head, mak-

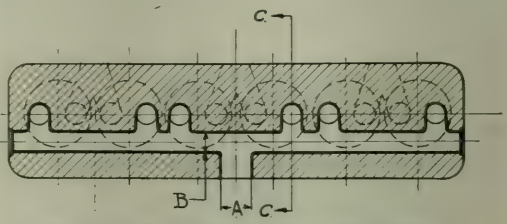


FIG. 14—DIAGRAM OF THE INTAKE-MANIFOLD PASSAGES

ing them of the shortest possible design. The engine cylinders fire in the order of Nos. 1, 5, 3, 6, 2 and 4; therefore, the flow of gas is continuous in both directions from the center. The average gas velocity at 3000 r.p.m. at *A* is 181 ft. per sec.; at *B* it is 175 ft. per sec.; just above the valve it is 192 ft. per sec. and at full lift of the valve it is 247 ft. per sec. The throat diameter of the valve is 1½ in.; the outside diameter is 1⅝ in.; the valve lift is 0.445 in. The area at *B*, Fig. 14, is 1.75 sq. in. and at *A* it is 3.39 sq. in. The tulip-shaped inlet-valve is used to lessen the resistance and keep the velocity of the gas as high as possible on entering the cylinder as an aid to turbulence.

The intake-pipe has already been described as shown in Fig. 6, on page 105. The application to the engine in the preliminary experimental form is shown in Figs. 7 and 8 on page 106.

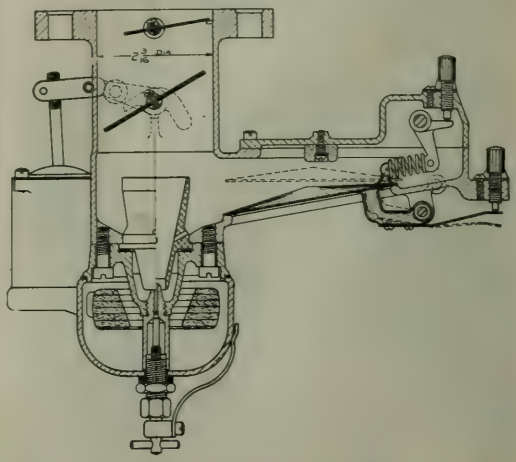


FIG. 15—CROSS-SECTION OF THE CARBURETER USED IN THE TESTS

Fig. 9 on page 107 shows the passage of the exhaust-gas pipe between the two center cylinders and the gas outlet pipe as used in the tests is shown in Fig. 19, on page 110, the valve at the end of the pipe being left wide open for all the runs. The engine is equipped with a Delco generator and single breaker-point type of ignition, with automatic and manual spark advance. A Willard battery was charged during the tests and also was used for starting. The spark-plug installation is shown in Fig. 9. Champion —Toledo No. A-63 metric two-piece plugs were used for all the runs. The perfect operation of these plugs had much to do with the ease with which the tests were run. Only six plugs were used and at the end of the runs they were in perfect condition. This is saying a great deal

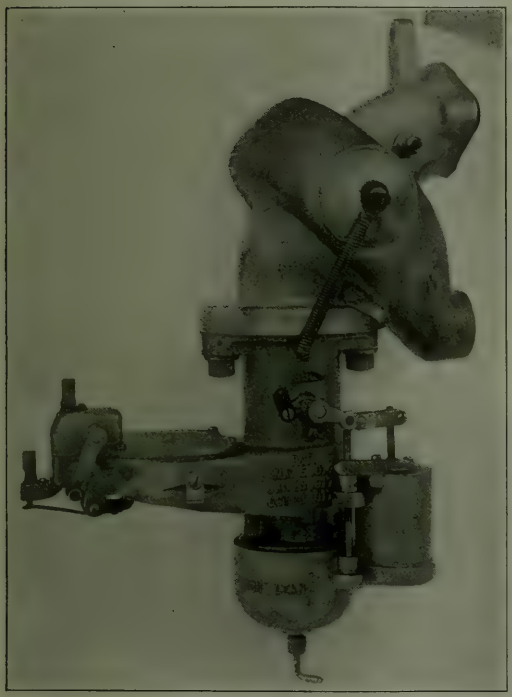


FIG. 16—THE INTAKE-PIPE FUEL VAPORIZER AND CARBURETER SHOWING THE KNURLED THUMBSCREW AND LOCK-NUT EMPLOYED TO ADJUST THE THROTTLE OPENING REQUIRED FOR THE PARTIAL LOAD TESTS CORRESPONDING TO THE CAR REQUIREMENTS

for the spark-plugs, considering the high-compression pistons, power output and speed of this engine.

Fig. 15 shows the 2-in., Johnson, Model-B carbureter used. The air-valve spring and strangle tube were first worked out for the low-compression piston tests. The same parts worked out nicely in connection with the 5 to 1 compression pistons, with only a slight change of adjustment on the air-valve spring. Otherwise, in each set of tests, all adjustments were kept constant for both partial and full-throttle loads.

Fig. 16 shows the knurled thumbscrew and lock-nut used to adjust the throttle opening required for the partial load tests corresponding to the car requirements. The spring shown kept the slack out of the throttle shaft. With the Sprague electrical dynamometer and the fine

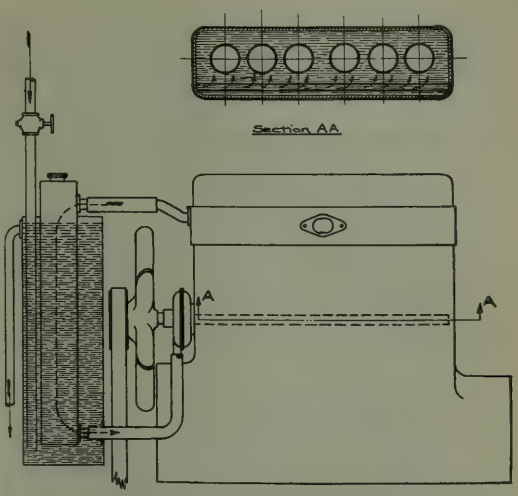


FIG. 17—DIAGRAM OF THE ENGINE COOLING-WATER CIRCULATION AND THE RADIATOR COOLING SYSTEM

throttle adjustment, the proper load and speed were obtained readily.

The section at *AA* in Fig. 17 shows the equal distribution of the cooling water to the cylinder sleeves. The water goes from the pump to the tube inside the cylinder block. Two holes for each sleeve give a uniform distribution of the water. This keeps all the sleeves at the same temperature, an important feature for equal gas distribution and smooth running. The engine cooling water circulates through a standard radiator as used

FIG. 18—THE CONNECTING-ROD, INLET-VALVE, EXHAUST-VALVE, PISTON-PIN AND PISTONS

on the car. The radiator is cooled by circulating water from an outside source around the outside of the radiator; that is, the cooling medium is water in place of air as used in the car. However, the engine water, having the same resistance as in the car, must have the same temperature drop, for the quantity circulated is the same in each case. The temperature of the engine water is controlled very easily by this apparatus, and is an exact duplicate of car conditions. The temperature of the engine water outlet was kept at 150 deg. fahr. for all the tests.

Fig. 18 on page 109 shows a photograph of the connecting-rod, inlet-valve, exhaust-valve, piston-pin and the pistons. The connecting-rod length is 11 in., the weight complete with bearings is 46.35 oz. and the center of gravity is 2.60 in. from the center of the crankpin end. Two pistons are shown at the upper part of the photograph. The one to the left is the 4.25 to 1 compression piston; the one to the right is the 5 to 1 compression constant-clearance type of piston. The view at the bottom shows the latter piston from a different angle. A set of 4.25 to 1 compression pistons of the constant-clearance type was not available for the comparative tests; however, $\frac{1}{8}$-in. wide piston-rings were used in each case and the 4.25 to 1 compression pistons were relieved at the side in an endeavor to give the pistons approximately the same bearing area as the other pistons. The cylinder clearance given the low-compression pistons was 0.005 to 0.006 in. and that of the high-compression pistons 0.0015 to 0.0025 in. The weight of three $\frac{1}{8}$-in. wide piston-rings is 1.82 oz.; that of the 4.25 to 1 piston, 13.52 oz.; that of the 5 to 1 piston, 18.65 oz.; and that of the piston-pin, 5.60 oz. The weight of the complete engine without the clutch is 660 lb. The weight of the complete powerplant, engine, clutch and transmission is 780 lb.

Testing Apparatus

Fig. 19 shows the Sprague dynamometer equipment. A Weston tachometer was used to indicate the speed. This was checked repeatedly by a revolution counter throughout the entire range of speeds used. The engine cooling-water temperature was obtained by a radiometer calibrated for the range used. The temperature control of the engine cooling water has already been described, and a diagram of it is shown in Fig. 17 on page 109. Fig. 19 shows also a view of the radiator installed within the cooling tank.

Particular care was used in weighing the fuel for each run. Two fuel tanks were used, one for a general supply and the other for weighing the fuel consumed in 120 sec. The time interval was obtained from the second hand of a watch and the use of a three-way valve connecting the two tanks to the carbureter. Both tanks were equipped with gage glasses so that the level of gasoline could be kept almost the same. This is important because the height of the level of gasoline in the carbureter bowl is a function of the pressure on the gasoline. It is obvious that, should the level of the gasoline in the carbureter change during the run, the fuel weighed would be in error by the amount of fuel it took to change the level. The main tank is shown at the extreme left of Fig. 19 and the weighing tank and Fairbanks silk scales are shown in Fig. 20. This scale balances readily within 1/100 oz., even when the rubber tubing connected with the fuel line is in place. The small line above the tank is for filling purposes and is connected with the gasoline pump that draws the fuel from the underground tank

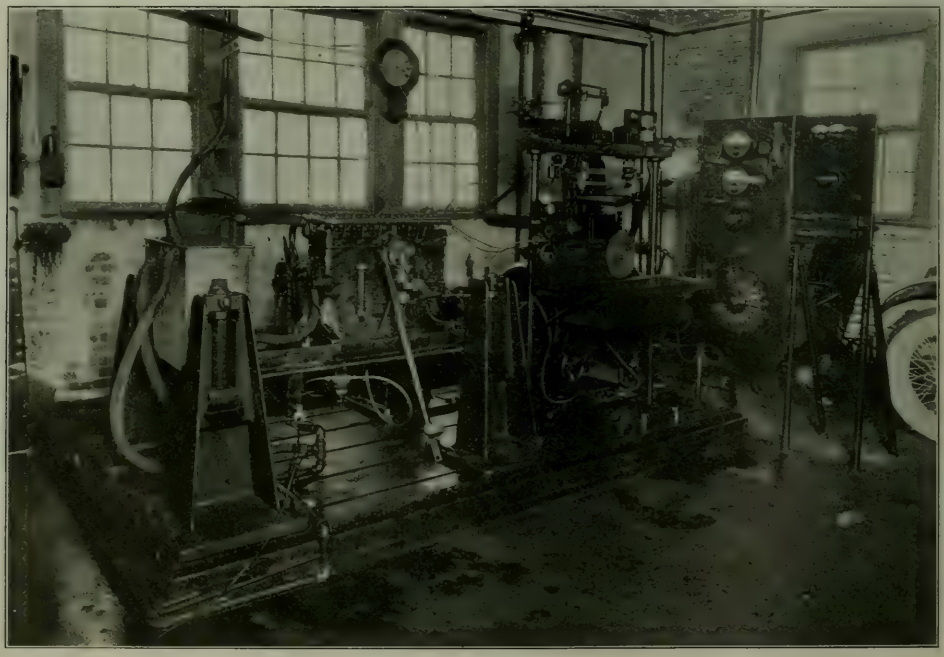


Fig. 19—Dynamometer Equipment Used

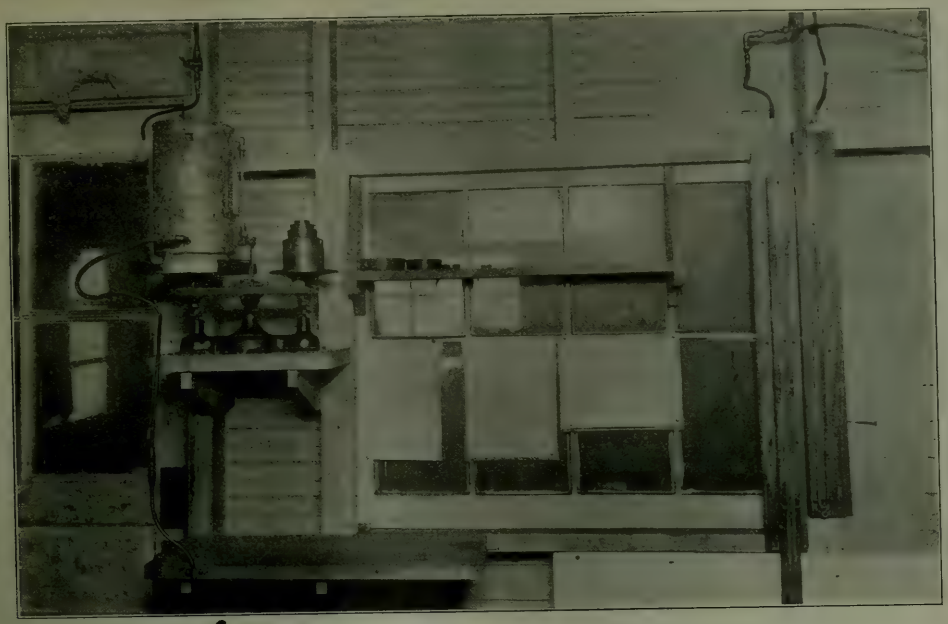


FIG. 20—FUEL WEIGHING SCALES AND MANOMETERS

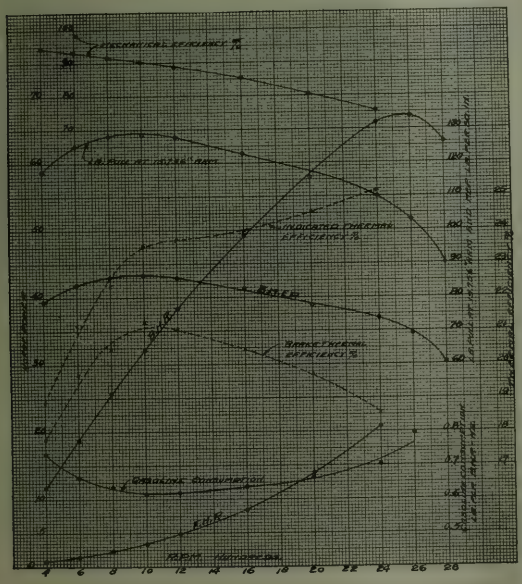


FIG. 21—ENGINE CHARACTERISTIC CURVES OBTAINED WITH AN OPEN-THROTTLE AND PISTONS HAVING A COMPRESSION RATIO OF 4.25 TO 1

outside the laboratory. At the right of Fig. 20, the mercury and water manometers are shown. These are connected to the intake-pipe on the engine.

During the tests the windows of the laboratory were opened and the room temperature kept close to 65 deg. fahr. on all the runs. The average barometer readings for comparative tests Nos. 1 and 5 were 30.23 and 30.22 in. of mercury respectively. (See Figs. 21, 24 and 29 on pages 11, 12 and 14.) The oil used in the tests was Mobiloil "A." The gasoline used was Target brand, made by the Western Oil Refining Co. The weight of a sample gallon was 96.80 oz. and the heat value per pound was taken as 19,500 B.t.u. in connection with the calculation of the thermal efficiencies.

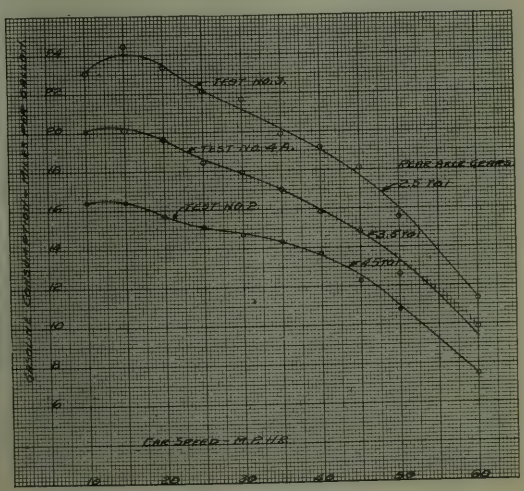


FIG. 22—CURVES SHOWING THE RELATION BETWEEN CAR SPEED AND FUEL CONSUMPTION USING PISTONS HAVING A COMPRESSION RATIO OF 4.25 TO 1

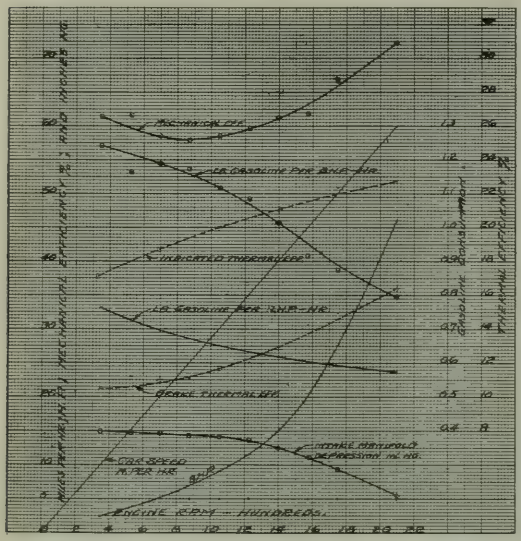


FIG. 23—ENGINE CHARACTERISTIC CURVES OBTAINED WITH A CONSTANT CAR SPEED, A 3.5 TO 1 REAR-AXLE GEAR-RATIO AND PISTONS HAVING A COMPRESSION RATIO OF 4.25 TO 1

COMPARATIVE TESTS

Some of the characteristics of the tests will first be mentioned and then curves will be shown giving the percentage comparison of results. Fig. 21 on page 111 shows the engine characteristics at full load with the 4.25 to 1 compression pistons. The maximum brake mean effective pressure comes at 1000 r.p.m., with a considerable reduction at 400 r.p.m. due to the delayed inlet-valve timing. The maximum fuel economy is 0.613 lb. per b.hp. per hr. The mechanical efficiency is very good at low speed but drops off rather fast as the speed increases. The peak of the power curve is at 2600 r.p.m.

Fig. 22 on page 111 shows the results of tests Nos. 2, 4A and 3, in terms of miles per gallon for 4.5, 3.5 and 2.5 rear axle gear ratios and 4.25 to 1 compression pistons. It will be noticed that a material increase in mileage is obtained as the engine load factor is increased by changing the rear-axle gear-ratio.

Fig. 23 gives the engine characteristic under constant-speed driving conditions with 4.25 to 1 compression pistons and 3.5 to 1 axle gears. It will be seen that the full-load brake characteristics have been changed greatly, while the indicated characteristics have suffered but little. The so-called friction losses, which include the pumping and thermodynamic losses, very materially lower the mechanical efficiency. Note that the engine is pumping against an intake-manifold depression of 15 in. of mercury at the lower speeds and the mechanical efficiency at 800 r.p.m. is only 58 per cent, compared with 91.7 per cent at full load.

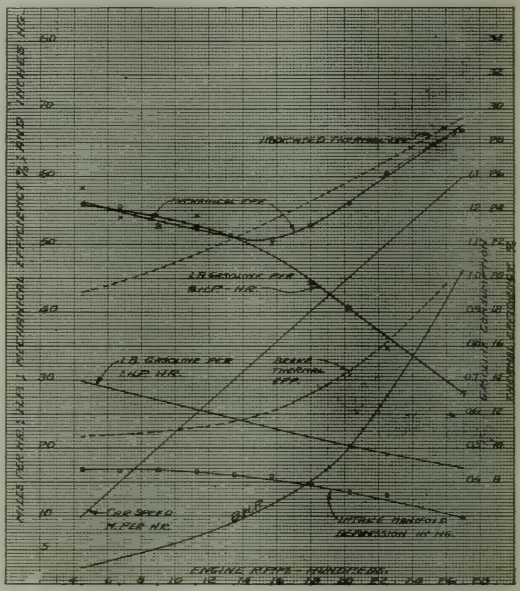


FIG. 25—ENGINE CHARACTERISTIC CURVES OBTAINED WITH A CONSTANT CAR SPEED, A 4.5 TO 1 REAR-AXLE GEAR-RATIO AND PISTONS HAVING A COMPRESSION RATIO OF 5 TO 1

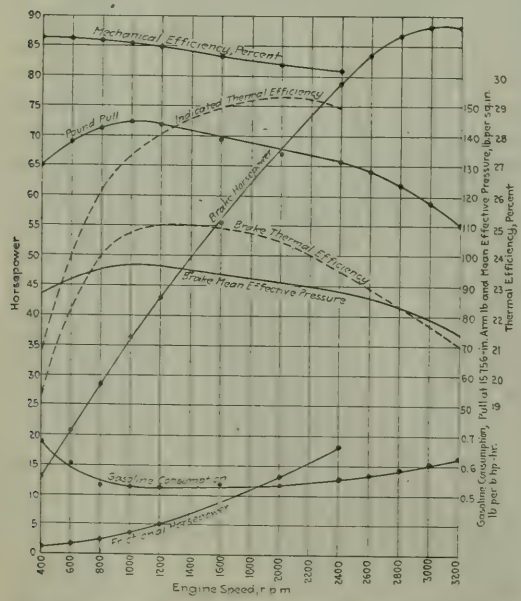


FIG. 24—ENGINE CHARACTERISTIC CURVES OBTAINED WITH OPEN THROTTLE AND PISTONS HAVING A COMPRESSION RATIO OF 5 TO 1

Fig 24 gives the engine characteristic when using the 5 to 1 compression pistons, everything else on the engine being identically the same. The readings given are not "snap" readings. The engine in all tests was kept running continuously and the results shown are those at which the engine runs with stability; that is, the result to which the engine settles at any given speed. It will be noticed that the maximum brake mean effective pressure is still at 1000 r.p.m., but it has increased from

86.2 to 96.9 as compared with Fig. 21 on page 111. It will also be noticed that the increase is greater as the speed increases. The peak of the power curve comes at about 3100 r.p.m. The fuel economy is greatly increased being 0.527 lb. per b.hp. per hr. at 1000 r.p.m. as compared to 0.613 lb. per b.hp. per hr. in the case of 4.25 to 1 compression. The mechanical efficiency is shown as not being as good below 800 r.p.m., but it is very much better at the high speeds, being 76.1 per cent as compared with 81.4 per cent at 2400 r.p.m. The

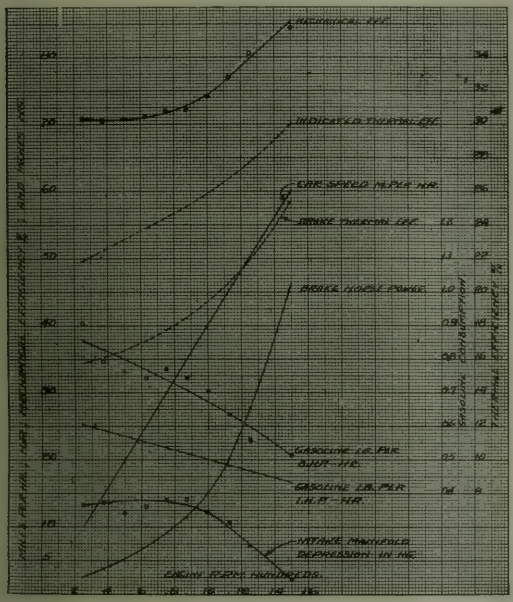


FIG. 26—ENGINE CHARACTERISTIC CURVES OBTAINED WITH A CONSTANT CAR SPEED, A 2.5 TO 1 REAR-AXLE GEAR-RATIO AND PISTONS HAVING A COMPRESSION RATIO OF 5 TO 1

maximum brake thermal efficiency is increased from 21.1 to 24.8 per cent.

Fig. 25 gives the engine characteristics in connection with constant-speed driving, with 5 to 1 compression pistons and 4.5 to 1 axle gears. Fig. 26 is for 2.5 to 1 and Fig. 27 is for 3.5 to 1 axle gears. Fig. 27 can be compared directly to Fig. 23, the only difference being the compression ratios. It will be noticed that the mechanical efficiency has not been materially changed; however, the fuel economy has been very materially increased. It is very gratifying to note that the relative increases are even greater than those of full-load characteristics. At 1000 r.p.m., the brake thermal efficiency has been increased from 11.5 to 14.1 per cent, and at 2100 r.p.m. it has been increased from 16.4 to 23.2 per cent.

Fig. 28 shows the miles per gallon curves for 5 to 1 compression pistons. This can be directly compared to Fig. 22. The results are materially higher all along the line. The overall increase at 15 m.p.h. is from 16.4 to 31 miles per gal., when changing both the compression and the axle gears.

In reference to what these curves represent, compared with actual roads tests, on long road tests the results agree very closely with the curves considering the

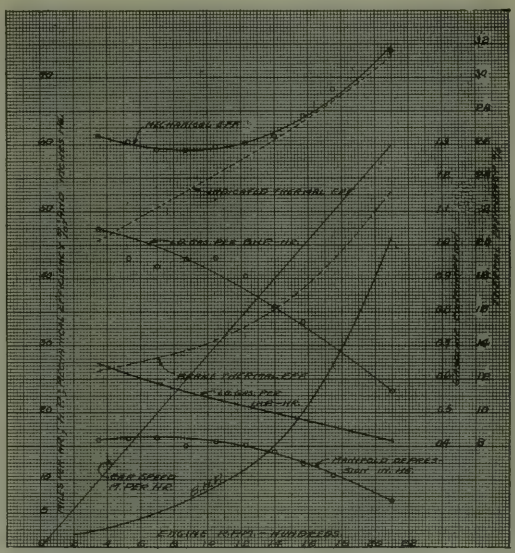


FIG. 27—ENGINE CHARACTERISTIC CURVES OBTAINED WITH A CONSTANT CAR SPEED, A 3.5 TO 1 REAR-AXLE GEAR-RATIO AND PISTONS HAVING A COMPRESSION RATIO OF 5 TO 1

amount of time the engine is idled and the nature of the driving. On the speedway, however, the results can be duplicated at constant driving. They also can be increased in case of using light engine oil and higher tire

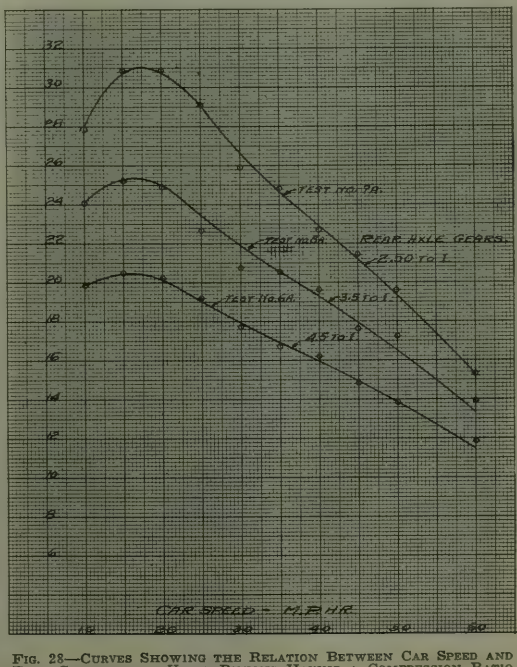


FIG. 28—CURVES SHOWING THE RELATION BETWEEN CAR SPEED AND FUEL CONSUMPTION USING PISTONS HAVING A COMPRESSION RATIO OF 5 TO 1

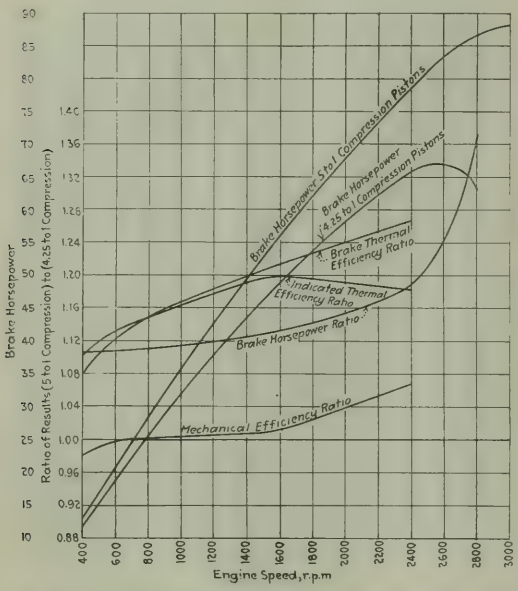

Brake Horsepower
Ratio of Results (5 to 1 Compression) to (4.25 to 1 Compression)
Engine Speed, r.p.m
Brake Horsepower 5 to 1 Compression Pistons
Brake Horsepower 4.25 to 1 Compression Pistons
Brake Thermal Efficiency Ratio
Indicated Thermal Efficiency Ratio
Brake Horsepower Ratio
Mechanical Efficiency Ratio

FIG. 29—A COMPARISON OF THE ENGINE FULL-LOAD CHARACTERISTICS

pressure than those used in the tests to set the standard of brake horsepower required.

PERCENTAGE COMPARISON OF RESULTS

Fig. 29 gives the engine full-load characteristics comparison. The comparison as a whole is entirely in favor

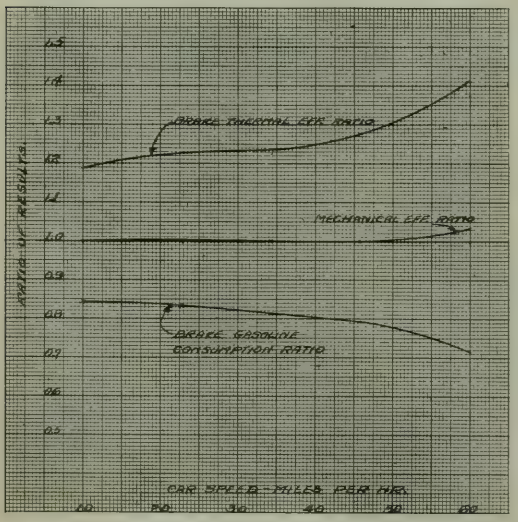


FIG. 30—A COMPARISON OF THE COMPRESSION RATIOS USING A REAR-AXLE GEAR-RATIO OF 3.5 TO 1

of the higher compression ratio, except a very slight loss in mechanical efficiency below 800 r.p.m. The increase in brake horsepower is marked, especially at the higher speeds. The percentage increase in power ranges from 10.5 to 37 per cent, between 400 and 2800 r.p.m. The most important increase is that of the brake thermal efficiency. This ranges from 8 to 26 per cent.

Fig. 30 gives the comparison of the compression ratio when keeping the rear-axle gears the same; namely, 3.5

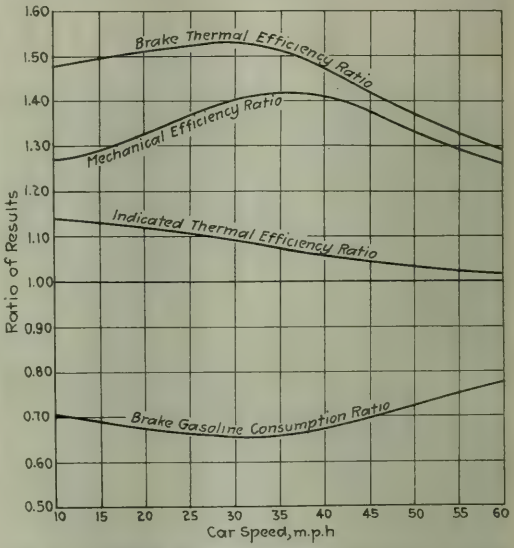


FIG. 31—COMPARISON OF REAR-AXLE GEAR-RATIOS USING PISTONS HAVING A COMPRESSION RATIO OF 5 TO 1

to 1. The mechanical efficiency remains practically the same, due to identical engine speeds in each case. The increase in brake thermal efficiency ranges from 19 per cent at 10 m.p.h. to 41 per cent at 60 m.p.h. The saving in gasoline is from 16 to 28 per cent, and, at average driving speed, about 18 per cent.

Fig. 31 gives the comparison of the rear-axle gear-ratios of 2.5 to 1, and 4.5 to 1, using 5 to 1 compression pistons. The percentage increase in mechanical effi-

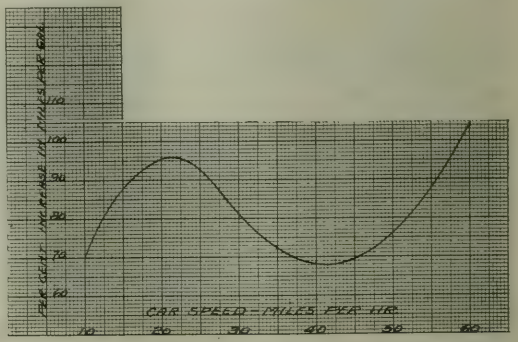


FIG. 32—PERCENTAGE INCREASE IN MILES PER GALLON OF FUEL USING A REAR-AXLE GEAR-RATIO OF 2.5 TO 1 AND PISTONS HAVING A COMPRESSION RATIO OF 5 TO 1 AS COMPARED WITH A REAR-AXLE GEAR-RATIO OF 4.5 TO 1 AND PISTONS HAVING A COMPRESSION RATIO OF 4.25 TO 1

ciency is very marked; the maximum gain is 42 per cent at 36 m.p.h. At 10 m.p.h. it is 27 per cent and at 60 m.p.h. it is 26 per cent. The maximum increase in the brake thermal efficiency is 53 per cent, at 29 m.p.h. It is 48 per cent at 10 m.p.h. and 29 per cent at 60 m.p.h. The gasoline saved is 30 per cent at 10 m.p.h.; 34 per cent at 29 m.p.h.; and 23 per cent at 60 m.p.h.

Fig. 32 gives the percentage increase in miles per gallon in the case of using 2.5 to 1 axle gears with 5 to 1 compression pistons, compared to 4.5 to 1 axle gears and 4.25 to 1 compression pistons. The increase in miles per gallon is 70 per cent at 10 m.p.h.; 95 per cent at 20 m.p.h.; 81 per cent at 30 m.p.h.; 68 per cent at 40 m.p.h.; 76 per cent at 50 m.p.h.; and 104 per cent at 60 m.p.h. These are indeed increases in economy that cannot be passed by lightly, yet they are by no means as great as the economy that is possible. Let us next consider the economy that is possible even with our present engines. For the sake of a name let us call it the "Ideal" economy.

Ideal Economy

We are a long way from the point where we utilize even the economy that is in our present engines. Fig. 33 gives a comparison which throws some light on what is meant. This chart is based on the actual engine economy existing at 60 m.p.h. when using 2.5 to 1 axle gears and 5 to 1 compression pistons. The economy is 0.513 lb. per b.hp. per hr. Using this economy and the brake horsepower required to drive the car at each speed, we derive a curve that we have termed the "Ideal" economy in terms of miles per gallon. It is not meant that this curve is practical with our present system of transmission of the power, but, if the proper gear ratio and engine size are used for any given speed, this economy can be obtained for the size of car used in these tests. From the ideal curve it will be seen that it is possible to get 49 miles per gal. at 10 m.p.h.; 45 at 20 m.p.h.; 39 at 30 m.p.h., and 31 at 40 m.p.h. The comparison is made with the results of 2.5 to 1 and 4.5 to 1 axle gears, in connection with the 5 to 1 compression pistons.

The increase in the miles per gallon over that of the results with 2.5 to 1 axle gears is 76 per cent at 10 m.p.h. and 45 at 30 m.p.h. The increase over that of the results of 4.5 to 1 axle gears is 146 per cent at 10 m.p.h., 115 per cent at 30 m.p.h. and 36 at 60 m.p.h. Further, the ideal economy comparison with the results obtained from 4.5 to 1 axle gears and 4.25 to 1 compression pistons is an increase of 104 per cent at 60 m.p.h.; 163 per cent at 30 m.p.h., and 199 per cent increase in miles per gallon at 10 m.p.h. These figures certainly are emphatic enough to arouse several changes in viewpoint of our present methods of applying our engines. Evidently there is room for very considerable progress and it is hoped it will be forthcoming in the near future.

It is hoped that the example of correlating important data will be carried out thoroughly in all our engineering investigations, thereby enlarging our viewpoint. Means should be developed making it possible to use very high piston compression ratios. It is felt certain that it can be done and to a great advantage from the point of economy. It is hoped that very decided progress will be attempted in piston development with a view to overcoming knocking and increasing the general efficiency.

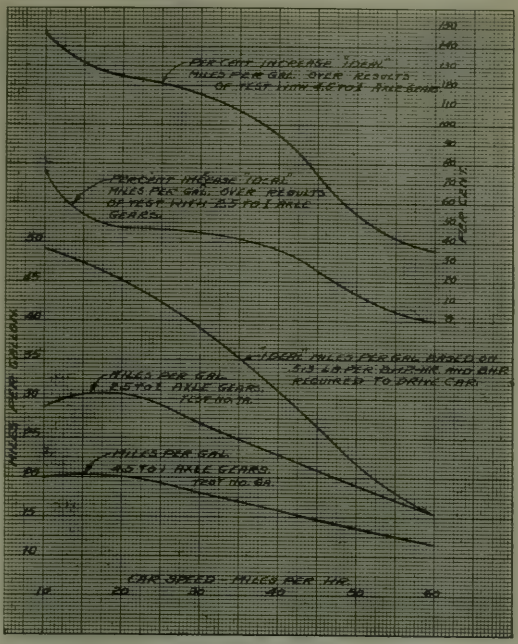

PER CENT INCREASE "IDEAL" MILES PER GAL. OVER RESULTS OF TEST WITH 4.5 TO 1 AXLE GEARS
PERCENT INCREASE "IDEAL" MILES PER GAL. OVER RESULTS OF TEST WITH 2.5 TO 1 AXLE GEARS
IDEAL MILES PER GAL BASED ON 0.513 LB. PER B.H.P. PER HR. AND B.H.P. REQUIRED TO DRIVE CAR
MILES PER GAL. 4.5 TO 1 AXLE GEARS TEST NO. 7A
MILES PER GAL. 4.5 TO 1 AXLE GEARS TEST NO. 8A
CAR SPEED MILES PER HR.
10
20
30
40
50
60

Fig. 33—A Comparison of the Economy That Is Possible with Present Engines Compared with the Results Obtained in the Tests

Our viewpoints on fuel vaporizers will, it is hoped, be greatly augmented and, as engines are made smaller to increase the load factor, carbureters will be made larger to avoid pumping losses and loss of maximum power. The fallacy that large carbureters are not as flexible or as economical as small ones is based, it seems, on the failure of certain types of large carbureter which it is thought are working on incorrect principles. It is recommended that we test the idea of using large carbureters to operate small engines, rather than that of using large engines to operate small carbureters.

The application of the indicated engine power should be studied from every angle. The tests show that an absurd waste is rampant in our present method. How far our ingenuity can go in this direction is hard to predict. One thing is certain, we must analyze carefully the gains that can be made. A close study from the brake-horsepower standpoint may justify changing both our transmission and our rear-axle drives. The latter combinations, together with engine developments, look the most promising at present. The progress we make undoubtedly will be measured by the extent to which we expand our engineering viewpoint.

Motor-Boat Standardization from the Naval-Architect's Viewpoint

By William J. Deed[1]

Motor-Boat Meeting Paper

POSSIBLE standardization is a very fascinating phase of the boat-building industry to me; in fact, it is the saving phase of that industry. As has been said, for many years the industry has drifted along because of the lack of standardized products that would create a year 'round market and enable builders to put the business on a manufacturing basis. In the past they practically have been idle for six months and overworked for the remainder of the year. Boats they have built have varied in size and type. Usually, with a dozen craft under construction, a builder would have no two that incorporated the same sizes of lumber. One would expect that two boats under way, each 40 ft. long, 10-ft. beam and 3½-ft. draft, having engines of the same horsepower, the same general arrangement and appearance, would be constructed generally of the same size of scantlings. But one keel may be of 4-in. oak and the other of 4¼-in. yellow pine; one may have ⅞-in. finished planking, while the other design calls for 1-in. planking when finished, the latter requiring 1¼-in. stock and wasting ¼-in. of material. The cabin floor-beams and the cockpit floor-beams may be different. They may be 1⅛ x 2¼ in. and 1¼ x 2⅛ in., whereas both might just as well be 1⅛ x 2 ¼ in. There are two bilge stringers or longitudinals; one may be 1⅛ x 3¾ in. and the other 1 x 3½ in., yet they could both be the same size.

To finish material to a specified thickness is costly to the boat builder and to finish a plank so that it will measure exactly 1 in. thick when the owner or his architect's representative puts a rule on it, requires the use of 1¼-in. stock and throwing away ¼-in. of material. The builder has charged the owner for 1¼-in. stock, but the material is lost and becomes nothing but sawdust. Few boat builders charge for the cost of planing the material. If thicknesses under 1 in. were not permissible, it would be better economy to specify 1¼-in. stock finished to at least a thickness of 1 in. and no one would object if this finishing were to 1⅛ in.

There is great advantage in having all bilge stringers the same size. They can all be run through the planing machine without an adjustment of the machine to provide for various thicknesses; they can be piled together after being milled and one can be picked from the pile with certainty that it is a bilge stringer without measuring the piece before it can be used. Hunting for pieces of certain size and measuring them takes time. This cuts into the boat builders' allowance for labor costs. If the contract is for a fixed price, the builder loses; if it is not for a fixed price, the boat builder passes the cost along to the owner. Standardization, then, benefits the builder, the customer and the boat builders' workmen.

Standardizing means increased production which, in turn, means a lower unit cost and a lower selling price. It means less profit per boat, perhaps, but increased profits on the yearly production. By having a product that can be marketed through the entire year, the boat builder can employ labor to advantage and he and his men know where they stand.

The procedure often repeated in connection with the building of a special boat is that early in the summer the prospective owner has an afternoon trip in his friend's motor boat. He likes it. He begins to get the boat fever. He can afford a boat and vows he will buy one for next summer. The summer passes and he considers buying one then, tempted by quotations on craft for sale at the close of the season. None suits him because he is particular about certain things. During the winter he looks over designs and obtains sketches gratis from various architects who are anxious for orders at that time, and considers. He is further enthused by the display of boats and engines at the motor-boat show. Nothing suits him; the $1,000 launch is too small and the $30,000 cruiser is too far beyond his means. He collects engine catalogs and more sketches, finally gets an approximate idea of the boat he wants and orders its design.

Several others have at this same time decided to go ahead. The architect and his draftsmen work early and late to handle the rush of six months' business in three. The contract is placed. There is competition among busy builders to get the best workmen and some offer inducements to obtain them for a few months of work. The boat builder orders the equipment, the engine and special lumber, and finds that the hardware manufacturers are loaded with unfilled orders. Great delay is experienced in getting materials. If the boat is to be delivered anywhere near on time, much equipment must be substituted for what was specified and usually this substitution is not a gain. Delivery is made in a grand rush. The owner is often forced, owing to the lateness of the season, to accept his boat before it should rightly leave the builders' hands. Consequently, many a trip is spoiled because of something which should have been attended to by the builder and the engine manufacturer before the boat was delivered. There are many cases where the prospective owner decides on his boat, places his order early and gets a perfect craft practically on time, but the condition I have described is ever-present, I am tempted to say that it is the usual condition. It should be corrected and the most satisfactory solution is the standardized motor boat.

Standardized Motor Boats

By standardized motor boats I do not mean standardized cruisers or runabouts of specific dimensions, but a complete line of motor boats of varied standard models and prices. It would then actually be possible for al-

[1] Nyack, N. Y.

most any man to select some craft that would fill his needs, one that he could see and test before he purchased, that would represent a standard value and that could be delivered on time, thoroughly tried out and ready to give uninterrupted service. We are only beginning to reach such a position. If the boat builders of the country produced standard boats of many sizes and types, one could choose a satisfactory craft among them.

Prices range from $200 to $30,000, with very slight price increases between models. Hence a good chance is offered for selecting a standardized boat. To be sure, one can hit in between 36 and 40 ft. and order a 38-ft. model with the galley forward instead of being aft, with an engine of one's own selection that perhaps will give a mile more speed, with built-in berths instead of extension transoms, with greater or less freeboard and a slightly different shape to the bow; but, instead of paying $8,000 for the boat one would pay $12,000. One would have exactly what is wanted, but the test of what one gets is whether it affords equal value in satisfaction and utility. I am not attempting to underrate the services of the men in my profession or the value of the specially designed and specially built boat. Designing boats is my business and that of many others. There is always the designing of special boats and consulting work that one can do. But the future of the small-boat building industry lies in adopting the standardized motor boat and constructing a line of boats for the quantity production of which the boat building plant is best equipped. Firms that do not standardize will find themselves hampered. If they standardize, they may have competition in progressing, but they will progress.

I do not mean that every builder must market a standardized boat built in great quantity. It would be fine if the builder were financed to do that, but boat builders have failed to take advantage of reducing the cost of labor by using quantity-production methods. If manufacturers, contractors and engine builders had followed the practices that boat builders have adhered to for years past, they would have failed in business. Most boat builders are frank to admit that they never made any appreciable profit; which is deplorable. For instance, many an estimate by a boat builder reads: Material $4,000, labor $6,000, profit-and-loss 20 per cent, or $2,000. His material costs are catalog f.o.b. prices; freight, cartage and express costs come out of the profit-and-loss item; his men must unload the lumber and cart it to the yard; they have to spend several days in tuning up the engine. All this comes out of profit-and-loss. The owner naturally insists on insurance until delivery, which may be delayed 30 days; and a further cost is entailed. It is small wonder if, when the boat is completed the record reads: "Loss $2,000." I have seen estimates by owners of respectable-sized boatyards that were made up with no overhead cost considered. The war changed all that. Many owners of boatyards obtained Government contracts. They soon discovered that an allowance of 50 to 70 per cent of the labor cost and 10 per cent of the material cost was necessary on their estimates. The boat builder now knows what "overhead" is; he also realizes that the greater number of times he can turn his capital over during the year, the lower will be his overhead per unit of product.

Summary

The advantages of constructing standardized motor boats are as follows:

(1) A constant market for the product

(2) The boat builder is better able to select workmen, train them, interest them in the work and hold them

(3) Valuable time can be saved during construction

(4) By knowing what his consumption of lumber will be, a boat manufacturer can buy in exact quantities without too great an excess for leeway

(5) The builder can buy materials at the most advantageous time, and does not need to buy them when others are clamoring for material

(6) The firm's books need not show thousands of dollars tied up in material and equipment that lie in the yard deteriorating, while waiting for possible future use. Many a builder could operate his yard an entire winter on the money thus invested

(7) The firm can reduce the deterioration of the plant by continuous operation. A building or a machine deteriorates much less when it is in use

(8) By having boats going through the shops continuously, the builder gives the impression of efficiency and being busy. Customers like to deal with the busy man; they avoid the store with no one at the counters and flock to the one having a crowd of purchasers

(9) By turning out a standard boat that is widely distributed and used, the builder soon knows if his product does not stand up in service and, by using equipment under identical conditions, he is able to remedy defects

In regard to the time that can be saved during construction, consider the actual hours lost by workmen in going back and forth to the stockroom for tools. The best men unconsciously waste hours in sorting over boards, counting out nails or screws and carrying galvanized rod to and from the blacksmith shop and the job. With standardized production the construction is carried along in stages. After the most satisfactory design is gotten out and the patterns and templets are made for all parts of the boat, when the first master boat is ready, one gang does nothing but select and mark lumber, and another gang mills it. The construction gang fabricates; each group does a certain part of the work. One group sets up the forms and the main frame, another bends the frames, a third installs the planking, and a fourth finishes and erects the joiner work. From the master boat a pattern of every part is made, and the parts themselves are built and stored near to the hulls. Bins should be installed close by each hull and kept supplied with sufficient quantities of proper-sized bolts, nails, screws and the like. The engine installation should be made at some given location in the shop. The boats should be shifted on a track, or an overhead traveling crane should serve the whole shop. All parts necessary for an installation should be kept near the job. In such ways time can be saved.

So far as I know, S.A.E. Standards are in use on all standard-sized motor boats; they should be, especially for such features as the taper of propeller-shafts. If the engine builders could unite upon standard dimensions for bed-plates, angles, the sizes of holes and the like, the movement would be much assisted. By manufacturing a nationally advertised product, the boat builder can obtain reputation and prestige that he would gain in no other way. He learns advertising, selling and shipping. He comes into contact with people and this broadens him. The whole idea of standardized motor boats offers advantages to all concerned.

A Suggested Rating Rule for Racing Cars

By H. M. Crane[1]

Annual Meeting Paper

In recent years automobile engines have been very generally rated for racing purposes in accordance with their piston displacement. The rule in most general use last year placed a limit of 183 cu. in. on this feature. The natural result of this method of rating has been to encourage the highest possible engine speeds with the object of obtaining the greatest possible piston displacement per minute. There is plainly no limit to the power that can be attained in this way, except that imposed by the great loss in mechanical efficiency at very high speeds and the increasing difficulty of maintaining a reasonable volumetric efficiency at such speeds. Much has been learned regarding the design of high-speed engines from the work done under this rating rule, but I think the time has come when we can expect to get very little more of value from a continuance of it for purposes of the commercial design of passenger cars and trucks.

Most automotive engineers are familiar with the features of engine design that have been developed under this rule. We find enormous valve areas, usually obtained by a multiplicity of valves; huge inlet pipes and carbureters, extreme valve-timing and very light reciprocating parts. However desirable these features may be for racing purposes, all experience indicates that they are highly undesirable in commercial engines. Those first mentioned make good performance at moderate and low engine speeds absolutely impossible with the present type of fuel, while the very light pistons used cannot be expected to give either reasonable wear or proper control of lubrication in commercial service.

I doubt whether it would be possible to formulate any rating rule that would tend to develop a really commercial type of engine for racing purposes, but I believe that it should be possible to do something to encourage engines of a type developing higher efficiency at lower speeds than is now the case. My suggestion is the development of a rule under which cars will be rated in accordance with the piston displacement per mile actually used by them. Such a rule would involve rear-wheel diameter and gear ratio, as well as the piston displacement of the engine. This would automatically allow the use of engines of varying size provided the other elements were properly proportioned. The use of gearboxes in most racing cars would perhaps make the application of such a rule difficult if not impossible in the case of road races in hilly country. In the case of track races or races on the flat, such a rule should be readily enforceable.

I am bringing forward this suggestion in the hope that it will induce automotive engineers to think along these lines. Racing is very expensive and I think the matter of getting more information of real engineering value out of it, if possible, is worthy of the most serious consideration.

[1] M.S.A.E.—Consulting Engineer, New York City.

RECORD GASOLINE PRODUCTION

THE production of gasoline in September set another new high point, the total production being 453,881,096 gal., or a daily average of 15,129,370 gal. This daily rate represents an increase of approximately 5½ per cent over the preceding month when the daily production was 14,327,143 gal. The daily average for September, 1919, was 11,319,419 gal., and for September, 1918, 10,486,532 gal. The average production for September of this year represents an increase of approximately 44½ per cent over the daily rate of 1918.

The stocks on hand at the refineries on Sept. 30, 1920, amounted to 288,195,394 gal., as compared with 371,125,419 gal. on the corresponding date of last year, a decrease of approximately 22 per cent. Compared with 1918 when the supply of gasoline on hand at the refineries amounted to 269,772,723 gal., the refineries had in their tanks approximately 10.7 per cent more gasoline than two years ago. At that time the stocks were being rapidly depleted, the lowest point being on Oct. 31 of that year.

Large as the September production was the figures for October surpassed it, the production for that month being 465,787,745 gal. This is at the daily rate of 15,025,411 gal., as compared with 11,724,411 gal. for the corresponding month of 1919, and 10,137,139 gal. for 1918, or approximately a 50 per cent increase in two years.

On Oct. 31, 1920, the gasoline in storage at the refineries was 301,283,731 gal., as compared with 288,195,394 gal. on Sept. 30, 1920. This indicates that the usual low point in gasoline stocks which occurs each fall has been reached and that during the succeeding winter months when climatic conditions curtail the use of gasoline consuming vehicles the refineries will have a chance to replenish their stocks. In both 1918 and 1919 the low point in the quantity of gasoline in storage at the refineries was reached on Oct. 31, the figures for these years being 250,328,329 and 354,160,071 gal. respectively. In 1917 the low point was reached on Sept. 30, the same as in 1920.

COMMERCIAL REACTION

WE are experiencing the natural sharp reaction from an unnatural period during which the elements entering into the making of prices were overplayed and tendencies indulged which upset the normal movement of commerce. There has been no weakening in the fundamental soundness of the nation's economic position. Credit resources are sufficient for legitimate commercial needs, even if commodity movements were in normal volume.—J. H. Tregoe.

WATER POWER

ACCORDING to the report of a French investigating committee the United States is rated as having 30,000,000 hp. in water power, Canada 25,000,000, Norway 7,500,000, Sweden 6,750,000, Austro-Hungary district 6,450,000, Italy and Spain about 5,500,000 each. Germany's water power is estimated at only 1,500,000 hp., and that of England is about 1,000,000 hp., but these two countries are richly compensated in coal.—*Power.*

Air-Temperature Regulation Effects on Fuel Economy

By Reuben E. Fielder[1]

Annual Meeting Paper *Illustrated with* Charts and Drawing

TWO serious problems confront the automotive industry in connection with the present fuel shortage. First, there is the problem of securing a much higher degree of economy with existing equipment; then, apart from this, there is the matter of future design. These problems are of nearly equal importance, since existing equipment will undoubtedly be in operation for a number of years to come; yet nearly all of the authorities on the fuel question are confining themselves to the future. As we see the situation, it is highly desirable that some attention be paid to the problem immediately facing us.

The steadily increasing cost of gasoline is a particularly serious matter for the Fifth Avenue Coach Co. The price paid today is practically four times what it was when we began to operate, although our rate of fare remains the same. We use several million gallons of gasoline each year; our fuel bill constitutes our second greatest item of expense. For this and many other reasons, we are constantly experimenting with devices of various kinds to improve fuel economy. Of the different devices that we have tested, our thermostatic temperature control for the carbureter appears to afford greater possibilities of saving than anything else that has been brought to our attention.

I will present briefly the results of our tests of this device. Although they show an appreciable saving, the device is still in its early stages of development and pre-

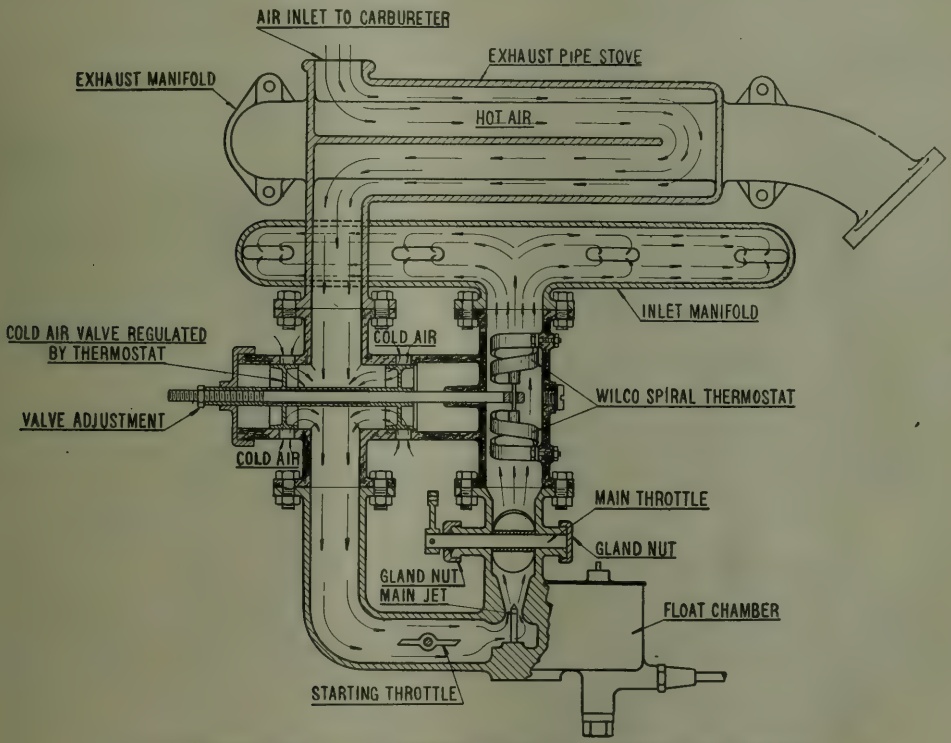


Fig. 1—Sectional Elevation of Thermostat Control for Air Entering the Carbureter

[1]M. S. A. E.—Mechanical engineer, Fifth Avenue Coach Co., New York City.

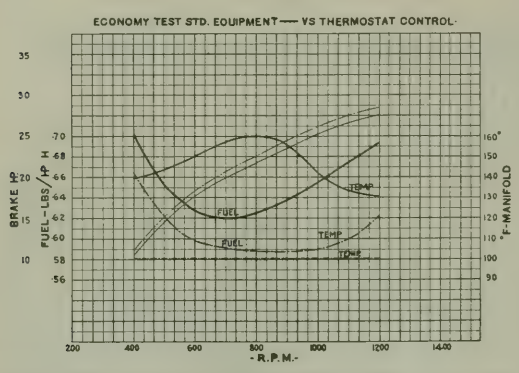


Fig. 2—Results of Economy Test Showing Saving in Fuel Consumption and Increase in Horsepower Obtained as a Result of Using the Thermostatic Control

sents further possibilities for research. This can be accelerated, we believe, by placing what data we have at this time before the automotive industry.

Description of Thermostat

Of the various factors governing the economical use of present-day fuel, we believe that the control of the charge temperature will play a most important part. Fig. 1 on page 1 shows the latest development of the thermostat for the control of the charge temperature in the inlet manifold. In this apparatus the air enters a stove. This is cast around the exhaust manifold in such a manner that the air passes along the top and then downward and back along the bottom of the exhaust manifold, which gives the maximum contact of the air with the hot surface. The air then passes down a pipe in which is located a double sleeve-valve controlling a cold-air inlet. The air continues on through the carbureter into the inlet manifold, where a spiral of thermostatic metal is located which connects to a spindle controlling the cold-air valve. The air, after mixing with the gasoline from the jet, strikes the thermostat which, according to the temperature, opens or closes the cold-air valve and thereby regulates the charge temperature which has been predetermined to suit the grade of gasoline being used. The temperature in the inlet manifold can be varied by adjusting the relation of the cold-air valve with its inlet ports. Air leaks are a source of trouble and it is necessary that all joint gaskets be tight. We have found also that it is advantageous to use packing glands around the throttle spindle.

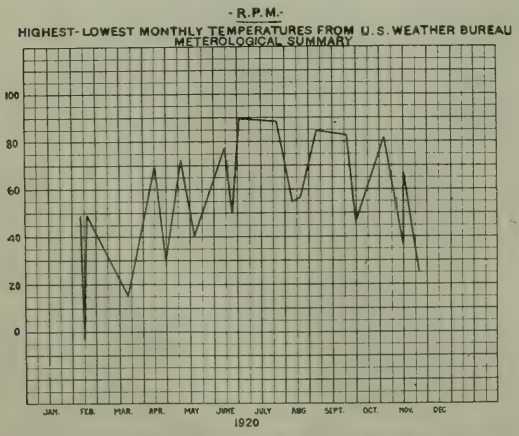

- R.P.M.-
HIGHEST-LOWEST MONTHLY TEMPERATURES FROM U.S. WEATHER BUREAU METEROLOGICAL SUMMARY
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
1920

Fig. 3—Maximum and Minimum Monthly Temperatures at New York City for the Year 1920

Comparative Tests

Comparative tests have been made with and without this thermostatic-control device, using the same engine, carbureter and similar equipment, under the same atmospheric temperature conditions. The results are shown in Fig. 2, where the average saving in fuel consumption is 7.85 per cent and a 5 per cent increase in horsepower was obtained when using the thermostatic control. We have obtained a greater saving than this in other tests, but the figures given can be considered most conservative. Table 1 shows comparisons taken from Fig. 2.

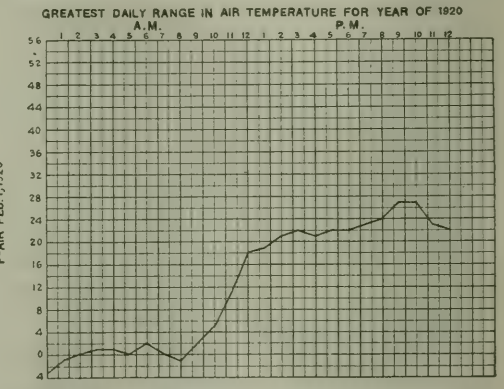


Fig. 4—A Typical Chart Showing the Daily Range in Temperature

TABLE 1—ECONOMY TEST

Speed, r.p.m.	Standard Equipment	Thermostatic Control	Difference	Difference, Per Cent
		Power Developed, Hp.		
400	10.5	11.2	+0.7	+6.6
600	17.7	18.0	+0.3	+1.7
800	21.5	22.5	+1.0	+4.6
1,000	25.3	26.3	+1.0	+3.9
1,200	27.6	28.2	+0.6	+2.2
			Average	+3.6
		Fuel Consumed, Lb. Per Hp-Hr.		
400	0.702	0.664	—0.038	+ 5.4
600	0.628	0.598	—0.030	+ 4.8
800	0.626	0.588	—0.038	+ 6.1
1,000	0.655	0.590	—0.065	+ 9.9
1,200	0.694	0.622	—0.072	+10.3
			Average	+ 7.3
		Manifold Temperature, Deg. Fahr.		
400	139	101	—38	—27.2
600	150	101	—49	—32.6
800	159	101	—58	—36.5
1,000	144	101	—43	—29.8
1,200	131	101	—30	—23.0
			Average	—29.8

The temperature in the manifold when using the thermostatic control was constant, whereas without this device it varied from 130 deg. fahr., as a minimum, to 160 deg. fahr., which showed a loss of power and increased consumption of fuel at all speeds, indicating a loss in volumetric efficiency due to excessive heat. This test was made at a time when the atmospheric temperature was 68 deg. fahr. What happens when the atmospheric temperature is around 90 deg. fahr. as in the

summer, or 0 deg. fahr. as in winter, can well be imagined.

Temperature Variation

Fig. 3 shows the highest and lowest temperatures by months for 1920, taken from the New York City station reports of the United States Weather Bureau. It will be noted that the temperature in February is 4 deg. below zero fahr.; yet in the same month it reaches 48 deg. above zero fahr., which is a range of 52 deg. fahr. In July the temperature reaches 90 deg. fahr. This is a considerable degree of heat, but there are many other things which make it worse; for instance, in summer we have the radiation from the pavements and the hot air coming from the radiator to contend with, and in winter bleak winds are encountered. In addition, we have a considerable temperature range within even a few hours, as is shown in Fig. 4, which is taken from the weather report for Feb. 1, 1920. At midnight, it is 4 deg. below zero fahr. and continues below zero until 8.00 a. m. Then it rises 20 deg. in the next 4 hr. and at 9.00 p. m. it is 27 deg. above zero fahr. This is a total range of 31 deg. for the day, which is by no means an exception.

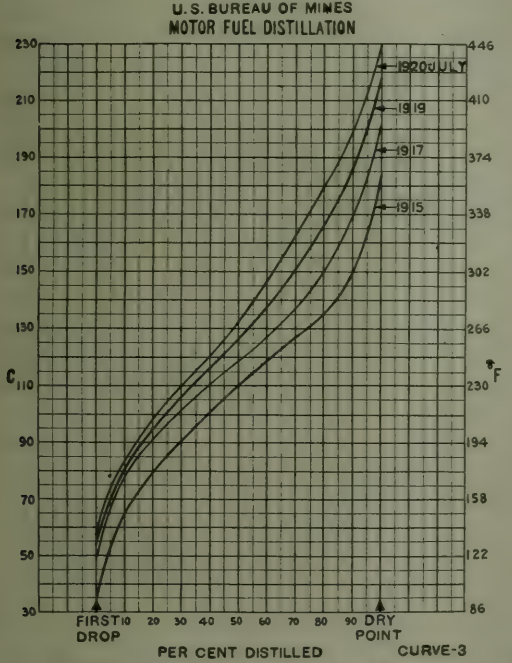


Fig. 5—Fuel Distillation Curve Showing the Variation in the Volatility of Gasoline Between 1915 and 1920

Fuel

The volatility of gasoline has changed considerably since 1915 as is shown in Fig. 5. This is a fuel-distillation curve supplied by the United States Bureau of Mines and the comparisons are shown in Table 2.

TABLE 2—COMPARATIVE FUEL DISTILLATION CURVES

Year	First Drop, deg. fahr.	Amount Distilled at 212 Deg. Fahr., per cent	Dry Point, deg. fahr.
1915	95	40	360
1920	133	22	446

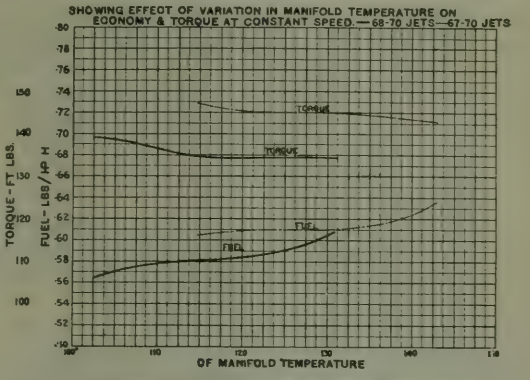


Fig. 6—The Effect of Variation in Manifold Temperature on Fuel Economy and Torque Developed

Desired Manifold Temperature

The thermostat is set to control the manifold temperature at about 102 deg. fahr. This temperature was determined upon after tests in which the engine speed was held constant while varying the temperature in the manifold, the power developed and the fuel consumption being recorded. The speeds selected were 700 and 1200 r.p.m., thus representing the high and low range of speed.

Fig. 6 shows two tests at 1000 r.p.m. with 68-70 and 67-70 jets. The No. 70 jets were used only for starting and idling speeds. The comparison with a No. 68 jet, shown in Table 3, is interesting and indicates a loss in volumetric efficiency due to the expansion of the air at high temperature.

TABLE 3—EFFECT OF VARIATION OF MANIFOLD TEMPERATURE ON ECONOMY AND TORQUE, WITH DIFFERENT JETS

Temperature, Deg. Fahr.	Jets 68-70	Jets 67-70	Difference	Difference, Per Cent
		Fuel Consumed, Lb. Per Hp-Hr.		
115	0.581	0.605	+0.024	—4.1
120	0.585	0.609	+0.024	—4.1
125	0.591	0.610	+0.019	—3.2
130	0.605	0.611	+0.006	—0.9
			Average	—3.1
		Torque, Lb-Ft.		
105	138.5	.....	.....	.....
110	136.0	.....	.....	.....
115	134.5	147.0	—12.5	+9.3
120	134.0	145.5	—11.5	+8.6
125	134.0	145.0	—11.0	+8.2
130	134.0	145.0	—11.0	+8.2
			Average	+8.7

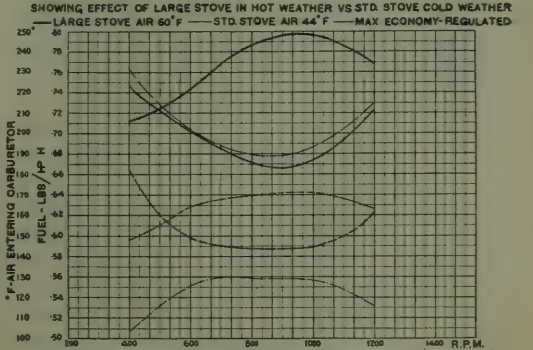

SHOWING EFFECT OF LARGE STOVE IN HOT WEATHER VS STD. STOVE COLD WEATHER
LARGE STOVE AIR 60°F
STD. STOVE AIR 44°F
MAX ECONOMY-REGULATED
°F AIR ENTERING CARBURETOR
FUEL - LBS/HP H
R.P.M.

Fig. 7—Effect Upon the Quantity of Fuel Consumed per Horsepower Hour with a Large Stove in Hot Weather Compared with That of a Small Stove in Cold Weather

TABLE 4—EFFECT UPON THE QUANTITY OF FUEL CONSUMED PER HORSEPOWER-HOUR OF A LARGE STOVE IN HOT WEATHER COMPARED WITH THAT OF A SMALL STOVE IN COLD WEATHER

Speed, r.p.m.	Large Stove, Air at 68 deg. fahr.	Small Stove, Air at 44 deg. fahr.	Difference, deg. fahr.	Difference, per cent	Combined Fuel Economy, per cent
400	0.748	0.764	+0.016	—2.1	0.756
600	0.701	0.704	+0.003	—0.4	0.703
800	0.671	0.680	+0.009	—1.3	0.675
1,000	0.674	0.687	+0.013	—1.9	0.680
1,200	0.722	0.730	+0.008	—1.1	0.726

Indications are that 102 deg. fahr. is the best temperature for the gasoline used and our thermostat was therefore set to maintain this temperature. The result was that 8 per cent or more of the fuel was saved.

Volumetric Efficiency

The necessity of considering this important matter is shown in Fig. 7, which illustrates the gain of the thermostatically controlled equipment over the standard equipment. Much of this gain is due to an increase in volumetric efficiency with the cooler air. For example, at 800 r.p.m., we have with the standard equipment a charge temperature of 160 deg. and with thermostatically controlled equipment 102 deg. fahr. This is a difference of 58 deg. fahr. An approximation of the amount of expansion for 58 deg. fahr. is 12 per cent. This means that there is 12 per cent less oxygen entering with the charge under standard conditions. Assuming that the same vacuum exists at the same speed, it will be seen readily how the temperature change from day to day affects the mixture quality.

TABLE 5—SAVING IN POUNDS OF FUEL CONSUMED PER HORSEPOWER-HOUR OVER COMBINED MAXIMUM AND MINIMUM ECONOMIES PRODUCED BY THERMOSTATIC REGULATION

Speed, r.p.m.	Combined Fuel Economy	Thermostatic Regulation	Difference	Difference, per cent
400	0.756	0.664	—0.092	+12.1
600	0.703	0.598	—0.105	+14.9
800	0.675	0.588	—0.087	+12.9
1,000	0.680	0.590	—0.090	+13.2
1,200	0.726	0.622	—0.104	+14.3
			Average	+13.5

Table 4 shows that the proper temperature to insure the greatest economy is not entirely controlled by volumetric efficiency. The effect of too much cold or hot air on economy, as compared with the thermostatic control, clearly shows the necessity of finding the correct temperature. Table 5 shows the saving over combined maximum and minimum economies produced by thermostatic regulation.

Conclusion

This paper is presented with the idea primarily of bringing out constructive criticism. We believe that the principle of thermostatic temperature control is correct, but its detailed application is still a matter for further experiment. That there are certain periods during the year when the average internal-combustion engine functions with the minimum amount of trouble is scarcely open to argument. This is due to the fact that at that time the atmospheric temperature is right. Our idea is to select this period and to standardize it for use throughout the remainder of the year. This certainly seems to be a logical arrangement. There is nothing new in connection with the theory of temperature control. Many others have worked and are still working on this problem. Among those who have cooperated with us I wish to mention E. R. Hewitt of the International Motor Co., who has done much constructive work along the lines indicated.

SUPERPOWER SURVEY

CONGRESS at its last session placed upon the Department of the Interior the duty of making a special investigation of the possible economy in fuel, labor and material that could be secured by the electrification of the railroads and industries of the region between Boston and Washington. The plan contemplated is a unified system of power generation and distribution, and its investigation has been called the superpower survey. This is now under way. The engineering profession and large business interests are giving this project support that is at once an indorsement and a promise of public confidence. The engineering staff engaged in this intensive study of the power needs and the means of meeting that demand includes men who have done pioneer work in applying electricity to the use of man; while serving on an advisory board are men of vision and experience, representing our larger railroads as well as electric railways, our manufacturing and mining industries and the engineering and chemical profession, busy men who have accepted an invitation to help direct this investigation along the lines of the greatest practical usefulness. Every industry that has to do with either making or using power is giving generous cooperation.

The area being studied, while only a small fraction of the United States, uses 24 per cent of the electric output of the central stations of the country and produces about 47 per cent of its manufactured products. It is properly termed the finishing shop of American industry. The report of this investigation will be completed June 30 next, and its purpose is to give an engineering solution to the problem of the demand of the Nation for greater production and better transportation. That answer is electrification, but its details must include an accurate statement of costs in capital and of savings in coal and labor.—From the recent annual report of Secretary of the Interior, J. B. Payne.

AIR MAIL OPERATION AND MAINTENANCE COST

CONTINUED operation of the Air Mail Service has brought about a marked decrease in the cost per mile flown. For the month of October, 1920, the average cost per mile flown on the New York City-Washington route was 78 cents including overhead as well as the cost of flying and maintenance. This was a reduction of 1 cent per mile over the previous month and 80 cents per mile from the figures for February, 1920. The cost of the New York City-Washington route in October was $14,985.20, as compared with $14,229.69 in February. The total number of miles flown increased from 9029 in February to 19,242 in October. The cost per mile flown for the entire service was 80 cents. This is due in part to high overhead and maintenance costs on the Salt Lake City-San Francisco route, the maintenance cost per mile alone being 74 cents.

In the month of October seven routes were in operation between New York City and Washington, St. Louis and Twin Cities, New York City and Cleveland, Cleveland and Chicago, Chicago and Omaha, Omaha and Salt Lake City, and Salt Lake City and San Francisco. The total cost of the Air Mail Service for the month was $123,618.68. The total number of miles flown was 154,486.

Style in Automobile Bodies

By George J. Mercer[1]

Annual Meeting Paper

Illustrated with Drawing

IT is not difficult to forecast the immediate future of the trend in automobile body models for large business or quantity production. Special designs vary according to the individual taste of each customer, but quantity business necessitates a design that will please the majority. The design must be a compromise between the old and the new. Its mission is not so much to excite comment as to placate users, because builders doing a universal business are bound to standard practice. I think that builders who produce what is termed a standard body model are not always satisfied with the appearance of their cars. On the contrary, I believe that the majority feel at times the urge to break away from stereotyped lines and produce something more distinctive but, if the volume of business is satisfactory, the most that such an effort will accomplish is some general refinement.

The design of an automobile body is one of the best advertising features of the car. The appearance alone often will make or mar a car sale. The body not only counts for appearance but, within its scope, it controls the comfort and much of the pleasure of motoring, and to some degree it insures the safety of the passengers. The potential benefits of an attractive body design as a sales booster are well understood; frequently the substitution of snappy uptodate body models will revive the selling force and add new life to the entire manufacturing organization. Provided the mechanical features of the car are sensible and correct, such changes are all that is required to produce a larger business.

Fortunately, several factors contribute and converge to make body changes practicable. For example, regarding the proportionate cost, in the case of an open car selling for $1,200 to $1,600, the body, including the top, windshield, mudguards and the like, costs about $400, or approximately one-third of the total cost. It is, therefore, not an expensive unit. The manufacturing outlay to produce an automobile body is at a minimum compared with the fixtures and tooling-up that are necessary to manufacture the mechanical units; in addition, the body is always made individually by each manufacturer, but the mechanical parts are most often commercial articles. For such reasons there is a certain flexibility about the body unit and, adding to this the greater apparent value for the money spent, changes in body styles are made practicable whenever the necessity arises.

The number of different body models that will prevail during the coming season is less than in past years. For example, a few seasons ago one manufacturer listed 14 body styles that were in regular production. The greatest number of models listed by one manufacturer during the past year was eight; the majority listed four and this latter number probably will be the number of different models made by most manufacturers in the coming period or, if the touring car is considered, in two divisions, a total of five styles.

Prevailing Body Types

The models that will prevail during the coming year are the five-passenger touring car, the two-passenger runabout, the five-passenger sedan and the four-passenger coupe. The seven-passenger touring car and the seven-passenger sedan will be made in limited numbers; at times the latter will be built with a division, thus making it a two-compartment car. The touring body, that has remained stationary for so long as regards development, is surely developing into two divisions to meet existing needs.

The sport-type touring body is usually a four-passenger design; it is intended to appeal to the younger element who want low racy lines that indicate speed. This type of body is generally painted in loud colors and is a compromise between the sport runabout and the touring body of conventional type; it has the same seating capacity as the latter and some of the smartness of the former. This sport model is an offshoot from the standard touring-body design, but manufacturers making both give them distinctive names and list them as individual models. However, the greater volume of business is still with the larger or five-passenger body. Although the sport model appeals to the minority, it is a very important factor. Its mission has already been shown in clarifying the runabout proposition.

There have always been runabout users who wanted a small body with seat room for more than the normal passenger capacity. The runabout logically has a two passenger body and when so made there is a certain definiteness in its design. The desire for more seat room brought out combination models in the past that have been short-lived, but those who require seat room for three or four passengers are best served by a close-coupled miniature-type four-door touring body. The runabout will hold its place as a necessary model, but it has been decreasing in numbers during the past two years. The five-passenger body seems to have been a satisfactory substitute for both the larger and the smaller body types. The runabout as made by the different manufacturers today is more uniform than formerly and has fewer freakish characteristics. When equipped with the all-seasons top, it is a sensible car for doctors and professional men.

The five-passenger sedan with four doors has undergone but one change within the past year. This has been the substitution of the straight for the slanting front, which simplifies manufacture and is more practical for small cars. The four-door sedan as we have it today comes nearer to meeting with universal approval than any body design that has ever been introduced. It has superseded all other forms of closed body for general use except the coupe, which finds favor because it is a minia-

[1] M.S.A.E.—Consulting body engineer, Saxon Motor Car Co., Detroit.

ture of the four-door sedan. The sedan has been simplified in construction by using belt molding that runs all the way around, and the same condition exists at the drip. These two moldings eliminate the welding of the panel. The drip molding covers the top material edge effectively or at least permits the use of a small corner molding under which the top cloth is finished, without its being evident.

The soft roof is used extensively. This roof is formed of waterproof material drawn over padded wooden strips and has been one means of keeping costs down during the period of high prices. Another feature on present-day closed bodies that differs from former practice is that the belt line is higher. Formerly, the window of the side was made as long as could be dropped flush in the door; today this line is carried at least 2 in. higher. The result is that the body looks lower and the quarter window light does not project so high above the body line when it is lowered.

The modern sedan has a four-door body and five-passenger capacity. It has a moderately square appearance. The lines are severe, with from 1 to 3-in. radius at the rear. The roof is moderately thin and has a straight molding line. Moldings are used on the doors. On the sedan moldings are used more than on any other body. This is done principally to give it a straight-line square effect and for economy in manufacture. On high-priced and specially designed bodies the use of molding is less conspicuous.

The favorite coupe has a four-passenger body. This body has had periods of oscillation between the two, three and four-passenger sizes, but has finally settled to the four-passenger size for quantity production. The smaller sizes of coupe have found favor with doctors and professional men but, for the majority of users the coupe is used and is expected to do duty in place of the miniature sedan. It has the compactness that makes it suitable for shopping and business and, as the fourth seat is of the disappearing type, a comfortable entrance is provided to any seat; in addition, accessible carrying space both inside and at the rear of the body is provided.

The bodies that have been enumerated are the most representative. They comprise the total of the models that builders of medium-price cars will list and market, because they meet adequately the requirements of the average buyer. Individual features naturally will be added to a limited extent, for their advertising value. Some will use the square rear corner; if it is used it is best adapted to the coupe and should be without molding.

The lack of a cheap closed car brought forward winter tops for open bodies. To some extent these met the needs of service, but their appearance was disappointing and they have all been superseded by the California top. This top fills service needs and adds to the general appearance of the car. When it becomes generally used and is in production, the price will fall and the open car so equipped will not cost as much as a coupe, although the cost is approximately the same at present.

A body with a well made California top is the ideal all-season car for the majority of users. The top is light and will therefore not rack itself to pieces. A top made with supports only at the back and front will deteriorate in this way, if lightness and flexibility are lacking in the construction. The cold and the warm seasons are sensibly provided for by fitting the panels with glass for winter, removing and replacing it with curtains for emergency use during warm weather. Manufacturers are recognizing the value of the California top and it constitutes regular equipment on both touring and runabout bodies with some builders.

Body Lines

The body lines that will prevail during a coming season are variable in their method of development. Specially built cars are the trial horses for developing new body lines. A very important factor and one that has an important influence on quantity production is the misuse of the prevailing style in body lines. This brings about a reaction toward more or less of a resumption of body lines that preceded the prevailing style.

The straight line with angular corners is giving way to moderately rounded surfaces, but the straight effect is simulated. The movement is not reactionary; it is illustrated in Fig. 1, which shows the forward end of the car and the body as far back as the windshield line. The purpose of Fig. 1 is to show how, with rounded surfaces on the radiator, engine hood and body shroud, the effect is straight through from the body top line. Three points, *A*, *B* and *C*, have been taken for illustration; the cross-sectional development is shown at *A-1*, *B-1* and *C-1*. The center of the radii of these three points is projected to the vertical plane to intersect with the lines *A*, *B* and *C*, and through these intersections a line *E* is drawn. The line *E* is parallel with the line *D*, which is a theoretical line that represents the top of the body side continued to the front. The point is that the metal forming the radiator, hood and shroud has its bending point on the line *E*. The line *E* can be slightly above or below the line *D* but, if it is reasonably near, when the front is painted and shows the light and shadow, it will appear as if the line *D* was continued right through to the radiator. It is not presumed that it will be sharp, as would be the case if the metal had a corner, but the appearance to the eye is harmonious.

An additional advantage is that the same hood must be used in production for open and for closed models. With a corner in the metal it is not easy to adapt it to the closed body; also, the height of the body sides will vary on different open bodies, so that the adoption of the plan illustrated in Fig. 1 simplifies the designing and has a beneficial effect on the manufacturing costs. The radius used on the corner is not arbitrary. The effect is most pronounced with a radius of about 1½ to 2 in., starting at the radiator. But almost any radius is permissible, always provided that the turning line of the metal is parallel to the theoretical line *D*. Coincident with the hood and radiator as shown, the flat top edge with a slight radius to the outer edge has superseded the bevel edge. The back corner of the body will be round, with a radius of from 4 to 6 in.; the sides will be of the moderate height of 22 or 23 in. and the back will be high, for comfort when using the rear seat.

Minor and General Considerations

Other features that have come into use and that increase the commonsense usefulness of the open body are the more general adoption of both inside and outside door handles; the use of rear top rest-irons that are taken off when not required; a superior quality of springs in the seat cushions, even in moderate-priced cars; higher hoods and radiators that give the appearance of vigorous motive power and, by their comparison in height with the body side, help to make it look lower. There seems to be a general tendency to use cowl lamps. The use of the sun visor has not been as general as it promised to be at one time.

The quarter window on both closed models has been made of less than conventional size and irregular in shape; we can expect those builders who have experienced success with it to continue to use it. The ventilator on top of the shroud is not needed, because the lower part of the windshield is movable and provides ventilation. All closed cars are made with large rear window for observation and in connection with it the mirror for the driver has real value. There is need of a better method of signalling than to have the driver wave his arm at the side. Touring cars are sometimes provided with a slit for this latter purpose in the side curtain when the top is up; again it is necessary to leave one curtain off. The signal should be automatic, operated by the clutch or brake, and should show a light also.

The value of having the design of the mudguards, radiator, hood, lamps, painting and trimming in harmony with the body design is fairly well understood; in fact, these features are the most conspicuous in distinguishing the different cars. The mudguards on most cars today are suited for their purpose and sensible. The crown guard with special formed edges is always an evidence of expensive toolwork. The front guard looks best when made long. The rear guard is at its best when it follows the contour of the wheel well down and is just below the wheel center. The width should never be less than 10 in. and an 11-in. width is better when used with running boards.

Radiators must be high and at least 24 in. above the frame, to permit a high hood and shroud. They look best when 1½ in. narrower at the top than at the bottom and there is a growing tendency to have them nickel-plated. The hoods will continue for some time to have long narrow louvres. The demand for as much enameling as possible, which includes at least the enameling of the hoods, mudguards and splashers, controls the painting combinations. The use of dark colors, without striping, prevails. The lamps also are enameled, being relieved with either a nickel rim or band. The greater durability of enamel as compared with painted surfaces, is one of the urges toward all-metal bodies, but changes in design and the initial high cost will cause the manufacture of the wood frame, the aluminum and the steel panels to continue for some time. Metal panels for the whole exterior except the roof are the standard. At times we have had closed bodies, generally coupes, with the upper panel made of imitation leather but commercially the metal panel has eliminated all competitors.

The trimming design on both open and closed bodies has remained the same for some time. The straight or French pleat continues to deserve favor. On open bodies leather for the seat and back coverings and imitation-leather coverings for the flats and back of the front seat have been the nearest to economy that real service would permit. The use of robe rails is usual, but the foot-rest is used intermittently. The general plan for all bodies is simplicity. Even the closed bodies have less ornamentation than formerly and the omission of toilet or vanity cases and flower holders is common. One dome light and, at times, corner reading lamps, constitute the sole appointments, except that the instrument-board may include a clock in addition to the usual necessary equipment, making this board the repository of practically all of the appointments.

The use of the window lifter is general for the doors of all closed bodies. The ornamentation on the silvered interior parts is in better taste and harmony than formerly and the material for the trimming is more frequently selected for its durability than for show. Cur-

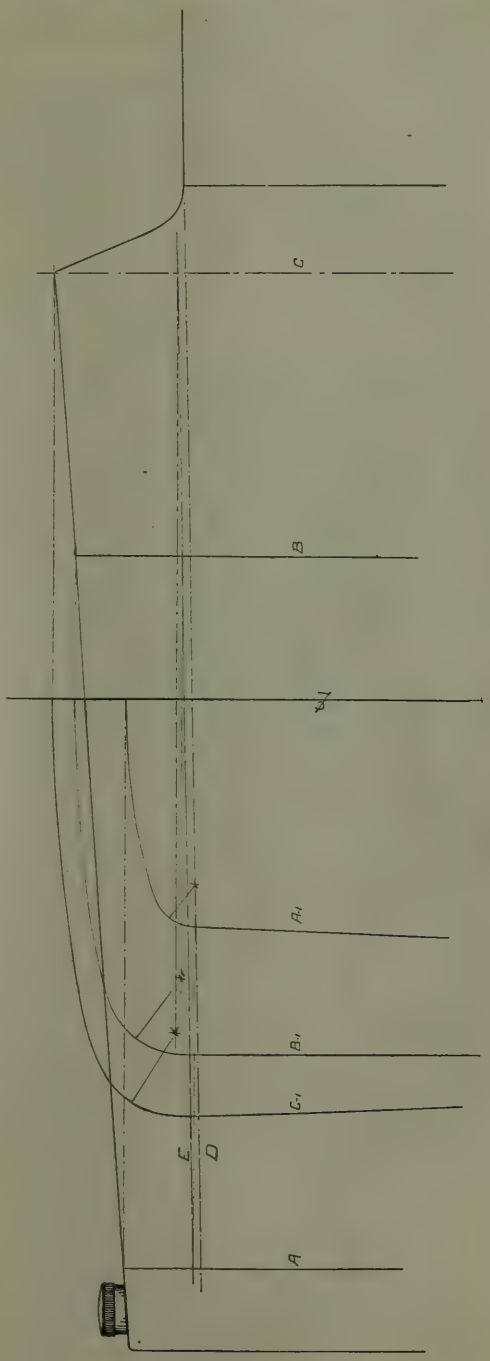


FIG. 1

tains are used for the rear, side and back windows only. Arm rests for the rear seat are in general use, but arm-holders or hat-racks are seldom seen.

While there is a general tone of simplicity, the tendency is to make up in quality what is lacking in variety. It is reasonable to believe that this will be the prevailing spirit for the season to come. The automobile body is so well known, so generally used and so thoroughly understood by the public, that its intrinsic worth is becoming its best advertisement.

Builders of the more expensive cars will always make their product of an approximately special-to-order class. Purchasers who are able to buy without counting the cost insist on body designs that are uncommon. Those who produce cars in large numbers for this class of trade usually follow a design that is not extreme, and that relies for its attractiveness upon the fine quality of the workmanship and the high quality of the material used. The chauffeur-driven car is the rule. The limousine and two-compartment sedan will prevail, with the town limousine, the town brougham and the cabriolet as the types having the lighter bodies.

THE HELICOPTER

AS an invention the helicopter is in embryo. For those who regret that they were unable to take any part in the very earliest developments of the airplane it may be some consolation to know that so far as the helicopter is concerned, if there is any field for it, that field is open for anybody to go in and do the real pioneering. It is not many years since engineers generally gave a negative answer to the question, "Is the helicopter possible?" They would express no belief in such a type of aircraft on the grounds that the power which could be developed would be barely sufficient to support the weight of the powerplant only. With time those views have changed, and advances in thermodynamical design and in applied aerodynamics have brought the construction of a practical helicopter within the bounds of possibility. But big problems have still to be faced, particularly those affecting stabilization, control and efficiency.

Airplane vs. Helicopter

The ability of the helicopter when in a more or less perfected state to rise from and alight on small spaces such as roofs, squares and gardens would be useful, and its ability to hover at any desired point in the atmosphere may possibly have advantages. The problem of alighting or rising when there is any wind, however slight, must be a very difficult one, and engineers believe that for some time to come it will be necessary to have large spaces such as the present airdromes. A large twin-engined commercial airplane can clear the ground after a run of 300 ft. or so, but if there are any trees in the vicinity, a space about four times as expansive is necessary to clear them.

As regards landing an airplane, it is not unreasonable to suppose that the power of vertical descent may ultimately be achieved. From the outset it appears that the helicopter must essentially be less efficient than the airplane as a power-absorber. A helicopter may be regarded as a practical combination of two fast-climbing airplanes united wing-tip to wing-tip and facing in opposite directions. An airplane ascending on a spiral path fulfils in the main the primary function of the helicopter, viz., ability to raise a load vertically. When the spiral path or helix is visualized as stretched out to become a straight horizontal flight path or trajectory, the superiority of the airplane over the helicopter is obvious. As regards hovering flight, it does not seem that the helicopter would serve many useful purposes in that condition. A passenger in a hovering helicopter would seem to be related to one who might charter a special train to take him to Charing Cross or any other railroad bridge to remain stationary on the bridge while he enjoyed the view of the river.

A Possible Line of Thought

When one considers any proposal for a helicopter the first step generally is to make a mental comparison of the possible efficiency with that of an airplane. Bevel gears will generally be found in helicopter propositions and not in airplanes. It is not unlikely that the inefficiency which characterizes the use of heavy gearing will be eliminated by causing the whole structure of the helicopter to rotate.

Large triplane wings set at a dihedral angle commensurate with the centrifugal stresses may be rigidly braced to a central vertical body structure about whose virtual axis they would rotate under the action of airscrews and engines carried on the wings or in a reverse direction with the engines out of action. Inside the rotating central body the pilot would be supported on a horizontal platform caused to rotate in the opposite direction by a small auxiliary engine. He would then have no rotary motion. The machine could be supported on an annular float. This ring-shaped float, being rigidly connected to the helicopter, and therefore rotating, would offer only frictional resistances on the water, and a cross-section in a vertical plane at any radius would have approximately a pear shape with the blunter end uppermost. On this float an endless train for accommodating passengers might be driven round in the opposite direction to the general rotary motion.

Through the tapering lower end of the central vertical body structure there might project a vertical telescopic member, on the lower end of which the controlling airfoil would be carried. The pilot would have facilities for extending and contracting this telescope, so that the moment of the air-pressure on the airfoil about the center of gravity might be changed and utilized for balancing the machine or for tilting it to obtain a component for horizontal motion. A similar telescopic member might be carried above, projecting through the upper end of the vertical body structure. On the other hand, it might be better to carry only a parachute in that place, for emergency purposes.—Douglas Shaw in *Aeronautics*.

ORDNANCE MUSEUM

A MUSEUM is being established at the Aberdeen (Md.) proving ground to exhibit enemy material used during the World War. This exhibit consists of about 60 pieces and was obtained from the various battle fronts by representatives of the Ordnance Department. It is known as the Engineering Collection. Descriptive pamphlets, drawings and photographs of each type are being made for the purpose of study. It is also contemplated to arrange for experimental firings of this enemy material. Further, it is contemplated to supplement and extend this collection by adding to it types of United States Army material, such as experimental pieces and obsolete service types, many of which are now available and are being brought from Sandy Hook proving ground.

Automotive Radiators

By KARL F. WALKER[1]

SINCE the publication of this article in the December, 1920, issue of THE JOURNAL, a written discussion has been received from E. H. Lockwood. This discussion and the author's reply are given below. For the convenience of the members a brief abstract of the paper precedes the discussion.

ABSTRACT

THE essential elements of an automatic cooling system are known to all engineers, but the importance and correct functioning of the various units of such a system are more or less vague to many. During the war the Bureau of Standards obtained considerable information on aeronautic radiators, but only a relatively small amount of information is obtainable on cooling systems for various other commercial uses.

When the spark ignites the gasoline vapor in the cylinder of an internal-combustion engine, the temperature may rise to about 2800 deg. fahr. and, in another moment, at the end of the intake stroke, the temperature may be only 300 deg. fahr. The mean temperature of the cycle will range from about 900 to 1000 deg. fahr. The effect of these temperatures on cast iron or steel, expansion, preignition, lubrication and the like, necessitates a means of cooling for which water has been found most satisfactory.

For such a cooling system the essential elements are a radiator, cooling fan, water-jackets and a means of water circulation. The factors controlling the heat flow to the water-jackets are the size and shape of the combustion-chamber, the thickness of the cylinder walls, the mean effective pressure of the engine, its cycle, speed and thermal efficiency. Proper circulation through the water-jackets in a pump circulating system is more important than the quantity of water contained therein, since lack of circulation in any one part of the jacket will cause overheating.

Radiator core construction is then discussed in some detail and a description of different types of cooling system is given. One of the most important factors affecting radiator performance is the air velocity through the core and this subject is dwelt upon in considerable detail. The subjects of cooling fans and general design factors are presented. The paper is illustrated with photographs and charts.

THE DISCUSSION

E. H. LOCKWOOD:—The author of this paper has given practical hints of considerable interest and value on radiator design. Nevertheless, it is doubtless true that the constants and data relating to this subject are still incomplete and faulty. Evidence of this is found in some of the constants given in the paper as representing the practice of an important manufacturer, which differ from the corresponding figures obtained by other experimenters.

One questionable point, lying at the foundation of radiator design, is the percentage of the heat generated in the cylinder that must be dissipated by the radiator. This comparison is made on the basis of the heat generated at full load, and the maximum heat dissipation of the radiator. The author makes the usual assumption, based on block tests of engines, that from 25 to 40 per cent is dissipated by the radiator. Tests of many automobile radiators that give satisfactory cooling show a heat-dissipating capacity of only 15 to 18 per cent of the heat generation at full load. The reason that the smaller percentage of heat dissipation can be used successfully is due partly to the assistance of the fan in air-cooling the engine, and partly to the very limited periods when full power of the engine can be applied, thus never taxing the radiator with full heat dissipation. If it is true that radiator heat dissipation of from 15 to 20 per cent of the heat generation at full load is sufficient for automobile practice, the usual figures can be reduced considerably.

Another questionable point in radiator design is to be found in the constants for heat dissipation per square foot of radiation. The author gives these constants in the form of a diagram, Fig. 6, which shows average values for several types of core, varying with the depth of core and adapted to air velocities of 1800 ft. per min. for trucks and 4000 ft. per min. for passenger cars. Two criticisms properly can be made of this diagram. The air velocities are too large for either truck or passenger cars, and the same constants cannot be used for all the different kinds of core. On the first point, it can be assumed safely that a car speed of 55 m.p.h. would be required to produce an air velocity of 4000 ft. per min. through the core. The variation of heat dissipation from different kinds of core is considerable. Water-tube radiators with continuous fins have about 15 per cent direct cooling surface and 85 per cent of indirect or fin surface. The fin surfaces cool down at high air velocities and lose much of their efficiency. On the other hand, the horizontal air-tube core has 100 per cent direct cooling surface, and the heat dissipation per square foot of surface is double that of the fin-and-tube type.

There is need for a table of heat dissipation constants for various types of core, based on experiments over a considerable range for air velocities, water velocities, temperatures, and the like. Probably much of this work has already been done in various laboratories, and would be available for compiling such a table of constants.

Tests have been made at the Mason Laboratory of the Sheffield Scientific School, Yale University, of a variety of automobile radiators. In some cases tests have been made also on the engines for which the radiators were designed. A typical example, having some bearing on the points under discussion, is found in the Ford engine and radiator. The standard Ford tube and continuous-fin core was found to dissipate 46,000 B.t.u. per hr. when operating under thermosyphon circulation at an air velocity of 1800 ft. per min. through the core. By dynamometer test the Ford engine was found to develop 18 b.hp. with a fuel rate of 0.85 lb. per b.hp. per hr. This corresponds to a heat generation in the cylinders of 18 x 0.85 x 19,000, or 290,000 B.t.u. per hr. The ratio of heat dissipated by the radiator in this case is 46,000 divided by 290,000, or 16 per cent. This radiator had an actual radiation surface of 65 sq. ft., including both sides of the fins. Its heat radiation per square foot was about one-half that given by the lower line of Fig. 6, but the lower value is explained partly by the thermosyphon circulation of the water.

KARL F. WALKER:—It is possible that the percentage of heat to be dissipated by the radiators of passenger

[1] M. S. A. E.—Chief engineer, Fedders Mfg. Co., Inc., Buffalo.

cars may be reduced somewhat, due to the fact that there are limited periods when full power of the engine can be applied. The percentages given are general, to cover various climates including those where conditions are severe. Some manufacturers use deeper radiator cores on cars to be operated in California and similar places. By so doing they obtain 10 to 15 per cent greater heat dissipation than is necessary for their Eastern trade. In truck and tractor design it is believed that these percentages are not too high, as they often operate under full load for comparatively long periods.

Professor Lockwood states that tests on passenger-car radiators giving satisfactory cooling show a heat-dissipating capacity of only 15 to 18 per cent of the heat generated in the cylinders. Engineers and automobile builders differ greatly as to what satisfactory cooling is. For example, there are two cars which use the same make of engine and carbureter, the same make and size of cooling fan and the same make of radiator; in short, the essential units are all identical. One of these builders requires about 15 per cent greater cooling surface than the other and claims he cannot get satisfactory cooling with less; yet the builder using the smaller cooling surface claims he has tested his cars in various localities and finds the cooling satisfactory. Another case at hand concerns two firms building cars of approximately the same price, which contain engines of the same type, the same number of cylinders and the same bore and stroke. The radiator on one of these cars is capable of dissipating 50 per cent more heat than the other. The engineer in this case is at present contemplating a change in the radiator to increase the cooling capacity still more, claiming that the present cooling is unsatisfactory. These are only two cases out of a number that illustrate how greatly engineers differ on what constitutes satisfactory cooling.

It is granted that 1800 ft. per min. is a higher air velocity than that obtained on the average truck or tractor; yet it is believed to be both a practical and desirable air velocity to maintain. The point was made that engineers were not giving due consideration to the importance of air as an aid to cooling. Using properly designed fans of ample diameter and having them correctly driven, there should be no difficulty in obtaining a velocity of 1800 ft. per min. through the average cellular or tube and horizontal-fin type of core.

Regarding an air velocity through the core of 4000 ft. per min., I believe that this is obtainable at a somewhat lower road speed than 55 m.p.h., if proper means are provided for the escape of the warm air from under the hood. However, a curve for an air velocity somewhat lower than 4000 ft. per min. would be of value for approximating radiator sizes for the few cars that are unable to obtain a road speed of from 50 to 55 m.p.h.

A table of heat-dissipation constants for various types of core under varied conditions would undoubtedly be very interesting. However, it must be remembered that in the manufacture of ribbon types of core the width of the water passage varies, due to the degree of hardness of the brass, the condition of the forming dies and similar factors and, as a result, the heat dissipation of two cellular cores of the same type made in the same factory may vary by as much as 15 per cent. The constants of the heat dissipated per square foot of radiation are only average values obtained from tests on a number of different types of core and are only valuable as an approximation.

Professor Lockwood states that, at high air velocities, a horizontal air-tube core having approximately 100 per cent direct cooling surface dissipates about 100 per cent more heat per square foot of radiating surface than a core of the tube and continuous-fin type having about 15 per cent direct cooling surface. Of course, these are two extreme designs of core construction. However, it is noted from tests run at the Bureau of Standards on a tube and continuous-fin type of core 3⅛ in. deep and having 12.3 per cent direct cooling surface, that the core dissipated 28.3 B.t.u. per sq. ft. per min. at an air velocity through the core of about 3200 ft. per min. It was noted further that the tests on a 3-in. hexagon-shaped single-tube core showed the dissipation to be 30.4 B.t.u. per sq. ft. per min. for the same air velocity. In this case we find that the core containing the larger amount of direct surface dissipated only 7.5 per cent more heat per square foot of surface than the one containing the smaller amount of direct surface.

Undoubtedly, the low heat dissipation of the Ford radiator tested at Yale University was due to the fact that it was tested under thermosyphon conditions. It was found that this radiator dissipated only 16 per cent of the total heat generated in the cylinders. Again it is a case of what constitutes satisfactory cooling. Professor Lockwood assumes that this radiator gives satisfactory cooling, but it is often found in driving Ford cars in hilly or sandy countries that the cooling is not ample. Tests run with a Ford car by the Motor Transport Corps through some hilly and muddy country necessitated the use of about 5 gal. of water on a 100-mile test run.

STATICAL LONGITUDINAL STABILITY OF AIRPLANES

REPORT No. 96, which has recently been issued by the National Advisory Committee for Aeronautics, Washington, is a continuation of the Committee's report No. 70, which was a Preliminary Report on Free Flight Testing. A detailed theoretical analysis of statical stability with free and locked controls is presented in the later report together with the results of many free flight tests on several types of machine. The results of these tests with locked controls are discussed and it is pointed out that the experimental results and those which might be theoretically expected are in agreement.

The theory of stability with free controls is not amenable to the simple mathematical treatment used in the case of the locked controls, but a clear statement of the conditions enables several conclusions to be drawn, one of which is that the fixed tail surfaces should be much larger than the ones which are movable. The discussion of the flight tests with free controls covers the effect of the position of the center of gravity, tail setting and slip-stream on the JN-4H plane. An analysis of the curves of forces on the control stick for the VE-7, U S A C-11 and the Martin transport airplanes is given.

Members who desire a copy of this report can secure one by writing the National Advisory Committee for Aeronautics, Washington.

Torsional Strength of Multiple-Splined Shafts

By C. W. Spicer[1]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

VARIOUS theories have been advanced regarding the torsional strength of multiple-splined shafts. So far as I am aware there are very little available published data on the subject. The results of some recently completed tests will, therefore, be of interest. In preparing this data it is intended to describe only the actual tests, the conditions under which they were carried out and the results obtained. No attempt will be made to develop the theory involved.

Superficially, it would seem obvious that the torsional strength of a multiple-splined shaft would probably be greater than that of a full round shaft having a diameter equal to the small diameter of the splined shaft. Data on this and related questions were sought experimentally.

A series of tests was run on 15 carefully machined shafts, as indicated in Fig. 1. The dimensions shown are the actual ones of the test-pieces, there being not more than 0.0005-in. variation in any shaft from the diameters shown. Heat-treating was very carefully carried out, and each specimen carefully checked by Brinell instrument on the ends and by scleroscope throughout the length. The Brinell numbers were all between 220 and 235, and the extremes of scleroscope hardness were 38 and 43. It was at first intended that the small diameter of shafts Nos. 1 to 5 should agree exactly with the small diameter of shafts Nos. 6 to 10. It was decided after the heat-treating had been done to avoid any straighten-

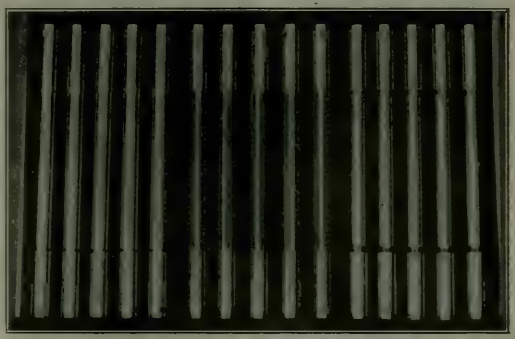


FIG. 2—THE 15 SHAFTS WHICH WERE TESTED

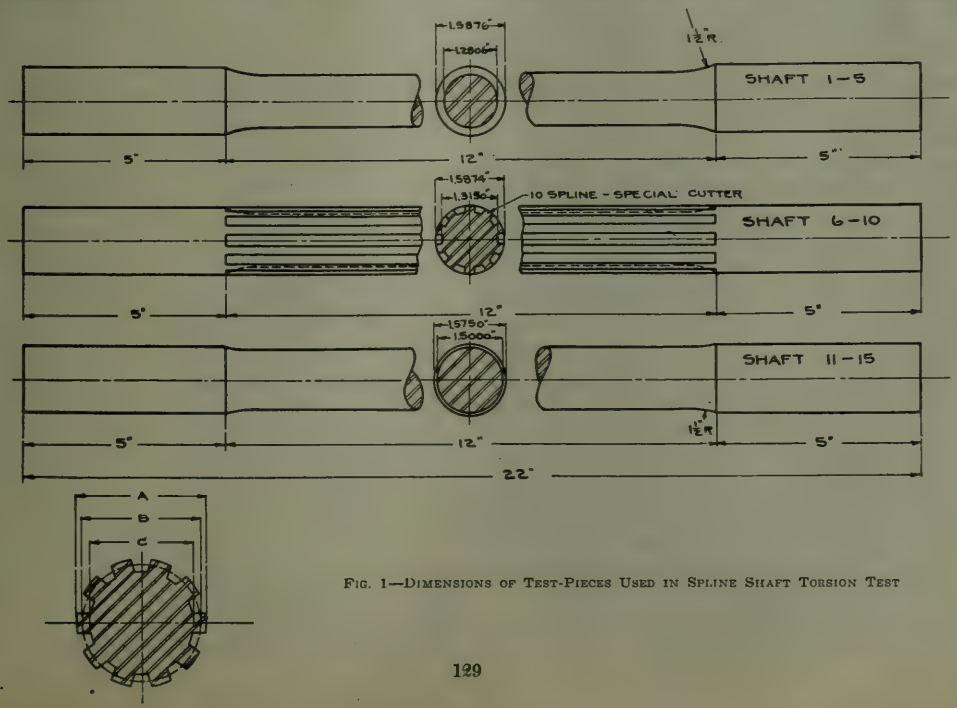


FIG. 1—DIMENSIONS OF TEST-PIECES USED IN SPLINE SHAFT TORSION TEST

[1] M.S.A.E.—Vice-president and chief engineer, Spicer Mfg. Corporation, South Plainfield, N. J.

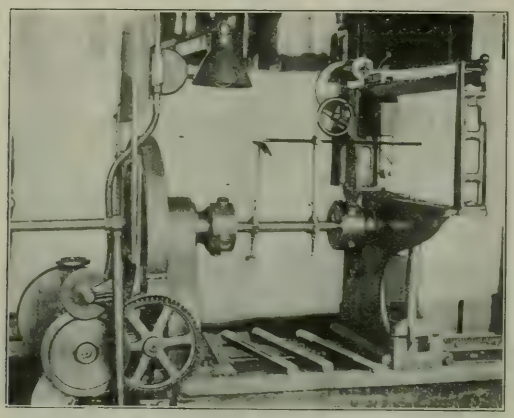


FIG. 3—THE TESTING MACHINE EMPLOYED

ing operations and, therefore, the small diameter of shafts Nos. 1 to 5 was reduced to a size that would clean up the most badly warped shaft by grinding. This also accounts for the large diameter of shafts Nos. 6 to 10 being below the 1⅝-in. nominal diameter. However, none of these details materially affected the results, as will be seen later.

It will be noticed that the small diameter of shafts Nos. 11 to 15 lies between the large and the small diameters of shafts Nos. 6 to 10 in approximately the relation shown in the lower left corner of Fig. 1 on page 129. This diameter represents a shaft which, according to one authority, is hypothetically equivalent to the splined shaft in torsional strength. That it is far from equivalent will be seen later.

Fig. 2 on page 129 is a photograph of the 15 specimens ready for the test and Fig. 3 shows the Olsen torsion testing machine with one of the specimens ready for testing. All readings from which the curves shown in Fig. 4 were prepared were taken by the Olsen troptometer attachment, which is plainly shown.

The results of the individual tests of the five specimens of each group were very uniform and it therefore does not seem necessary to give the detail curves of each specimen. The curves shown in Fig. 4 represent the average of the five shafts in each group, and are self-explanatory. Curve *a* is the plotted average of shafts Nos. 1 to 5. Curve *b* is curve *a* corrected for a diameter equal to the small diameter of shafts Nos. 6 to 10 for convenience in comparing with curve *c* which is the average of shafts Nos. 6 to 10; and curve *d* is the average of shafts Nos. 11 to 15.

The position of the letters *a*, *c* and *d* also indicate the location of the so-called Johnson elastic limit; that is, the point at which the unit increment of deflection per unit of load increase is 50 per cent greater than at the beginning.

Comparing curves *b* and *c* it will be readily seen that a splined shaft of the dimensions given has a torsional elastic limit of approximately 18 per cent less than a full round shaft of a diameter equal to the small diameter of the splined shaft although the deflection for any given load below the elastic limit is greater in the smaller shaft. The elastic limit of the hypothetically equivalent shaft is very much higher.

For the convenience of those who have not studied tor-

(*Concluded on page* 199)

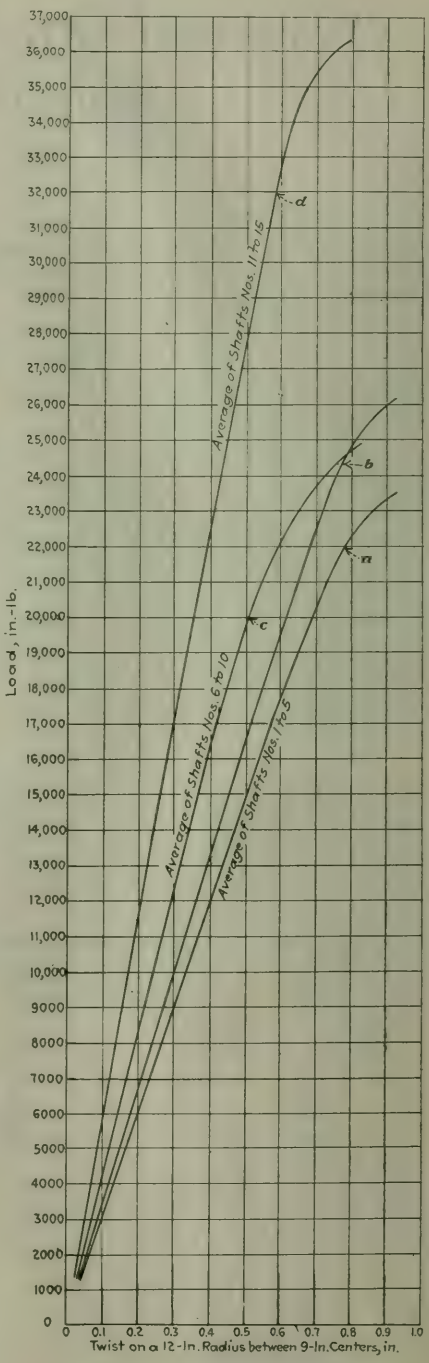

Load, in.-lb.
Twist on a 12-in. Radius between 9-in. Centers, in.
Average of Shafts Nos. 11 to 15
Average of Shafts Nos. 6 to 10
Average of Shafts Nos. 1 to 5
a
b
c
d

FIG. 4—COMPOSITE CURVE OF TEST RESULTS

Notes on Current Fuel Research

What line of development or research are you following now in connection with fuel study? Why have you selected this particular means of solving the problem?

On Nov. 8 letters were sent to a number of members interested in the internal-combustion engine fuel problem. These letters propounded several questions relating to the problem which the members were requested to answer. The questions and some of the replies that were received in response to the letter are given on this and the following pages.

R. J. BROEGE:—We are concentrating our efforts on improving the vaporization of gasoline fuel by applying the hot-spot manifold system, since it seems to be the most logical method adaptable to the constant-volume engine using gasoline as a fuel.

O. B. ZIMMERMAN:—The chemical treatment of fuels to reform their molecular structure is being prosecuted because experiments have shown that such processes are effective and provide more suitable fuel, at no increase in cost.

P. S. TICE:—Both a qualitative and quantitative examination of the conditions surrounding the formation of the working charge is being studied, with respect to vapor content in the charge and final temperature of the charge. This study is being made because, aside from certain inherent chemical differences among fuels, their satisfactory use in an engine is almost wholly a problem in charge formation.

D. FERGUSSON:—We have, of course, experimented with various methods of using the high end-point fuel that is now on the market. These have consisted of hot-spot intake manifolds, water-jacketed manifolds, manifolds jacketed with exhaust gases, and devices similar to the fuelizer. We have not at present obtained any results that would warrant us in changing from our standard equipment of water-jacketed manifold, with a thermostat cutting out the radiator when the temperature of the water in the jacket gets below 160 deg. fahr.

L. M. STELLMANN:—Practically all of our development work in connection with the adaptation of present fuels to our air-cooled engine has been toward the utilization of exhaust heat on the exterior of the intake manifold. The greatest portion of the heat is applied above the center of the manifold, where the largest amount of the mixture of air and fuel is encountered as it goes into the cylinders. The heater is arranged so that, as heat passes toward the extreme ends of the intake manifold, the temperature is reduced approximately in proportion to the amount of mixture encountered. The amount of heat used in connection with this intake-manifold heater is controlled from the seat by the operator, and it is possible to use the entire exhaust gas from three cylinders of a six-cylinder engine.

In connection with cold-weather starting, we have developed an electric vaporizer or starting carbureter in which air and gasoline are passed over an electrically heated coil. This mixture of heated air and gas is passed into the intake manifold above the throttle-valve and consequently under a comparatively high vacuum. We find that an engine can be started with this device by using kerosene, or at least a very low grade of gasoline, under temperature and climatic conditions reaching 20 deg. below zero fahr. Flooding the engine badly, when starting under cold-weather conditions, is overcome by the use of this electric vaporizer in combination with the rapid warming of the incoming charge by the use of a large amount of exhaust heat about the intake manifold. These two methods have practically eliminated crankcase dilution and consequent piston, cylinder and bearing wear.

It seemed most desirable to use the heat in the exhaust to raise the temperature of the incoming charge, vaporize it more fully and bring the overall efficiency of the gasoline engine nearer that attained under warm-weather operating conditions.

G. A. GREEN:—We have been developing a method of thermostatic inlet temperature control because we believe that we can effect greater economy in this way with less direct expense and inconvenience than in any other manner.

HUGO C. GIBSON:—We have been studying the use of heated intake-manifolds provided with exceptionally large surfaces in their interior, where those portions of the fuel having a high boiling point can be caught and slowly evaporated on the heated surfaces without excessive addition of heat.

The mixture becomes somewhat hotter than is necessary with low end-point gasoline and necessitates the use of decreased maximum compression to avoid autoignition. Since there is no liquid fuel within the cylinder, cracking and detonation are avoided. This results in somewhat decreased volumetric efficiency, but in increased general ability and smoothness, considering the character of the fuel available.

H. L. HORNING:—I am studying the subject of turbulence because it

(1) Is the factor we know the least about
(2) Controls flame propagation
(3) Deals with fuels as we find them
(4) Decreases the tendency to detonate
(5) Maintains a lower and more uniform temperature on the unjacketed sections of the combustion-chamber, such as the piston, exhaust valve and spark-plug
(6) Insures less after-burning
(7) Permits higher compression and hence high mean effective pressure and high thermal efficiency
(8) Means greater flexibility and acceleration
(9) Affords the most effective physical means of controlling all causes of thermodynamic losses

C. A. NORMAN:—I am following, so far as possible, all lines of research promising to lead to greater engine

economy or other relief in the fuel situation. Several general lines of development appear profitable to me.

The heated inlet-manifold does not avoid fuel waste, poor distribution, crankcase dilution and carbon formation during the starting-up period. The fuel converter seems to be superior in this respect. At car speeds of 20 m.p.h., the flame propagation from a single spark-plug does not carry combustion through the clearance space of even comparatively small engines. For a long time, two spark-plugs have been known to increase economy and power very materially; this fact should no longer be neglected. Increased compression in general leads to greater power and improved economy. Insofar as "doped" fuels permit increased compression without knocking, they should be encouraged. Nevertheless, to build up an entirely new industry and create a new source of expense to engine users to save fuel by increased compression, is not economically sound if some other means of increasing economy can be found.

The injection engine is one solution. Recent reports published in this country and Europe show that injection engines of automotive dimensions and speeds are within the realm of legitimate technical development. Steam offers the possibility of operation on any kind of fuel, with an economy that may prove fair at reduced loads.

Have you substantiated any new and interesting engineering facts related to the fuel problem since the Summer Meeting?

C. A. NORMAN:—The facts that have come to my attention since the Summer Meeting of the Society emphasize more than ever the possibilities of the injection engine.

O. B. ZIMMERMAN:—It is possible to handle any known liquid fuel obtained from natural mineral resources, even asphaltic fuels, with returns of 76 per cent, where former processes produced only 15 per cent from the crude. Kerosene, gas oil, fuel oil, residue and crudes of all kinds, can be treated by this process.

R. J. BROEGE:—We have developed a special exhaust-jacketed manifold of our own design, using kerosene as a fuel in the gasoline engine with slightly lower compression. Gasoline is used as fuel for starting.

HUGO C. GIBSON:—The turbulence theory is a red herring across the trail. The detonation theory, with the assumption that the more rapid the rate of flame propagation is, the greater the noise will be, is incorrect because very high-test gasoline, or benzol, each giving an exceptionally high rate of flame propagation, does not detonate, the benzol being inherently less subject to detonation than the gasoline. In other words, these high-grade fuels are less subject to detonation, or knock, or auto-ignition, as it really should be called, because the temperature at which they will ignite automatically is much higher in the case of benzol and high-test gasoline than in the case of low-grade gasoline or kerosene in the order named.

What is your present practice on compression pressures, using gasoline, kerosene or benzol?

L. M. WOOLSON:—Our testing work is confined to gasoline. On our small-bore passenger-car engines we are using 70 to 75-lb. per sq. in. gage compression, measured at 120 r.p.m. On our larger truck engines, we are using compression pressures between 55 and 60 lb. per sq. in. On our aviation engines, we use between 110 and 120-lb. per sq. in. compression, measured in the same way.

P. S. TICE:—For gasoline, we use from 85 to 95 lb. per sq. in., and for kerosene from 70 to 75-lb. per sq. in. gage compression.

L. M. STELLMANN:—We use a compression of about 70 lb. per sq. in. with gasoline. With kerosene, the compression under the same conditions would not run over 60 lb. per sq. in. With benzol, the pressure probably would be as high as 80 lb. per sq. in. We have found that benzol practically will eliminate preignition or detonation, even under the highest operating temperatures encountered in our air-cooled engines.

C. A. NORMAN:—Given a correct design of head and inlet passages, 60 to 65 lb. per sq. in. compression would appear to be possible with kerosene; with gasoline, it would reach 70 to 80 lb. per sq. in. With lighter gasolines and efficient cooling, very much higher compressions are known to be practicable.

HUGO C. GIBSON:—Depending upon some elements of design of the engine, such as the cylinder capacity and the relation of the bore to the stroke, the following gage pressures give good results, the pressures being determined accurately with an O'Kill indicator or manograph at 800 r.p.m.

	Pressure, lb. per sq. in.
Gasoline	65
Kerosene	55
Benzol	100

H. L. HORNING:—We have no established practice as yet. With each improvement in turbulence we increase compression pressures. We are not so interested in compression pressures as compression ratios. We use the same compression ratios now for kerosene as gasoline, namely 4 to 1.

R. J. BROEGE:—The compression pressure depends somewhat upon the size of the engine. For our smaller engine, the compression ratio is approximately 4 to 1, giving about 75 lb. per sq. in. gage at 125 r.p.m., and the largest engine is arranged with 3¾ to 1 ratio or about 65 lb. per sq. in. gage at 125 r.p.m. These compressions are reduced approximately 20 per cent for kerosene.

G. A. GREEN:—We employ 85-lb. per sq. in. compression when using gasoline.

Have you any definite recommendations on spark-plug location relative to the valve, cylinder center, or combustion-chamber?

H. L. HORNING:—Theoretically the plug should be (*a*) at the minimum distance from the hottest spots; (*b*) in the path of greatest turbulence; (*c*) toward the center of gravity of the combustion-chamber; and (*d*) if possible, pocketed rather than opposite a pocket. All these points should be considered as the introduction of turbulence changes the controlling factors greatly. In a mixture free, or relatively free, from turbulence the detonation phenomena are shown plainly by flames in a glass tube, while a turbulent mixture tends to control these phenomena, including retonation and reflected sound waves. At low speeds the phenomenon of combustion in a cylinder tends to obey the properties of burning gases in a tube, while at moderate speeds turbulence controls flame propagation and at high speeds it prevents any local rapidity of flame propagation but enflames the whole mass in a minimum time, assuring the highest temperatures with the minimum dissociation. At high speeds turbulence is a maximum and tends to overcome the defects of decreasing volumetric efficiency and mechanical efficiency by improving the efficiency of combustion.

HUGO C. GIBSON:—The cylinder center is the preferred position, meaning in the center of the head.

P. S. TICE:—In a combustion-chamber having small temperature gradients spark-plug electrodes should be located as near as possible to the center of mass of the compressed charge. Where the combustion space has very hot parts or pockets, the spark-plug should be located in the hottest part.

R. J. BROEGE:—The spark-plug location should be nearly central in the combustion-chamber and at a point centrally between the piston and valves, so that the exhaust and also the incoming gas sweep across the points of the plug.

L. M. WOOLSON:—Although we believe that the spark-plug location has an important bearing on detonation, the best location must be determined experimentally for each particular design of engine.

L. M. STELLMANN:—We have gone rather extensively into the location of the spark as well as its time of action. Using a hairpin-electrode plug we were able to place the spark at the center of the combustion space and close to the piston. A careful road test showed that locating the spark at the center of the combustion space required 7 deg. less advance at 20 m.p.h. than was required under the same conditions when using a standard short plug. An automatic advance was then used and road acceleration tests were taken at intervals of 5 deg. of advance or retard from the original position. Our tabulated results indicated clearly that a variation of 5 deg. in advance was important and should be considered when maximum performance was desired.

O. B. ZIMMERMAN:—The plug should be cooled by the incoming gases and a location near the center of the gas to be ignited is beneficial.

C. A. NORMAN:—From the point of view of economy and power, as well as avoidance of knock, spark-plugs ought to be centrally located for a minimum distance of necessary flame travel. Naturally, the points should be swept by the fresh charge. Captain Hallett and H. R. Ricardo have pointed out that a hot exhaust valve at some distance from the spark-plug is apt to cause a knock. It is better to have the inlet farther from the spark-plug than the exhaust valve, if a central location between the valves is not possible. Mr. Ricardo in a recent paper[1] states that the increase in power obtainable by using two spark-plugs can always be equalled by sufficient spark-advance with a single spark-plug. With compression as high as feasible, too great spark-advance will in time mean knock. Multiple spark-plugs, according to Ricardo, give greater flexibility without spark adjustment, and indirectly greater power and economy by making increase in compression possible. Captain Hallett, as well as many earlier experimenters, however, states categorically that increases in power of something like 11 per cent can be obtained by multiple spark-plugs.

Have you succeeded in developing a means of increasing compression without resultant detonation?

L. M. STELLMANN:—We cannot hope to increase compression indefinitely without experiencing detonation. An extensive series of spark-plug tests was run in our laboratories with the following results.

In the first series we tried a long heavy plug with a skirted extension. This plug fired perfectly for ½ hr. after the electric ignition was cut off. From this point the preignition decreased as the metal was removed from the skirt until the skirt vanished. In another series we used heavy hairpin plugs 1/16 in. in diameter. The preignition then decreased with a decrease of the diameter of the wire. With a compression ratio of 4.8 to 1 we found that wire of 0.030-in. diameter burned fast at the points of spark passage. A wire of 0.040-in. diameter did not cause any preignition except under very adverse conditions that would be seldom encountered.

R. J. BROEGE:—It has been our experience that the limitation of compression is governed greatly by the composition of the fuels used and that detonation can be held to the minimum by properly cooling the combustion chamber and the head of the piston.

HUGO C. GIBSON:—We feel that the allowable compression is determined by the specific temperature at which the fuel mixture will automatically ignite.

C. A. NORMAN:—In injection engines the knock does not figure. Personally, I prefer to lay emphasis on this fact, not because I am not keenly interested in developments making increased compression and better economy possible with carburetted engines, but because there is not a sufficient number of engineers in this country today who strive to keep the possibilities of injection engines before the eyes of the profession.

Have you applied the turbulence theory effectively and what provisions did you make to create or maintain turbulence?

P. S. TICE:—Yes. We recommend localizing the combustion space as much as possible over the valves in an L-head engine, constricting the passage fairly well from this space to the cylinder bore proper, and forming the localized combustion space to conform as nearly as possible with what are supposed to be the general flow lines of the charge as it is compressed into this space.

C. A. NORMAN:—Turbulence should be created not only by velocity through the valves, but by special means, during ignition and combustion. Various ways of doing this have been suggested, and a number are successful in related fields.

L. M. STELLMANN:—We have not been able to prove to our own satisfaction that the turbulence theory has any particular bearing on the performance of our engine. On the other hand, we do believe that overhead valve construction lends itself much better to the thorough turbulence of the charge.

O. B. ZIMMERMAN:—I consider that the shape of the combustion space and the method of entry are chiefly responsible.

H. L. HORNING:—Gas velocity and shape of combustion-chamber are the important considerations affecting turbulence.

Have you any information that you may disclose regarding intake-manifold and distribution phenomena?

R. J. BROEGE:—Our manifolding is so arranged as to produce the best vaporization at the point of greatest diffusion of the heavier particles in the fuel. We also endeavor to locate the hot-spot on the manifold as close to the intake valves as possible, to reduce volumetric loss and minimize increase of temperature.

L. M. STELLMANN:—We have found it desirable in connection with the intake manifold and distribution to keep the temperature of the fuel as distributed into each cylinder as nearly even as possible throughout the whole

[1] See *Engineering*, Sept. 3, 1920, p. 325.

engine and the gas should pass into the intake-valve port at a temperature of between 100 and 120 deg. fahr.

L. M. WOOLSON:—As a general proposition we have found with a six-cylinder manifold that it is very desirable to extend a baffle from the center of the manifold to a point near the carbureter so as to form two independent passages, one leading to the forward three cylinders and the other to the rear three cylinders. This eliminates loading, particularly at the lower speeds, and also effects important improvements in distribution. We have applied this idea to several different types of six-cylinder engines and can definitely state that such baffling is highly desirable.

HUGO C. GIBSON:—Based on my belief that turbulence and high velocity in the intake manifold are not desirable, and that a properly formed mixture of fuel vapor and air is what we require in the cylinder prior to compression, it is best to increase the size of the intake manifold with the result that restrictions are reduced and a torque curve flatness is maintained.

H. L. HORNING:—Proper velocities and investigation of shapes with glass models plus heated surfaces as per the S. A. E. Fuel Report enabled us to attain 0.60 lb. per hp-hr. consumption and 82 lb. per sq. in. m.e.p. on kerosene.

If you have experimented with "doped" fuels, please state what the results have been.

O. B. ZIMMERMAN:—There is considerable valuable work to be done along this line with net results of value, although most of the work is unnecessary while fuels are as obtainable as at present.

P. S. TICE:—We have done nothing whatsoever with "doped" fuels, inasmuch as others, notably Mr. Midgley, have been giving this aspect of the situation much attention.

L. M. STELLMANN:—One and two per cent mixtures of anilin oil with gasoline seem to make practically no difference in the running of our engine.

HUGO C. GIBSON:—Benzol mixed with gasoline is the only practical "doped" fuel at this time. It permits the use of higher compressions without knocking, because the temperature of auto-ignition is raised due to the presence of benzol. However, the use of benzol is not a solution of the problem, on account of the poor national distribution of that commodity. A benzol and gasoline mixture gives more power, greater economy, greater smoothness and more comfort than straight gasoline in any engine, the advantages being particularly noticeable in high-compression engines in which the mixture is not heated to a great degree as in the older type of engine. The advantage is not so marked in engine designs adapted to the use of the present high end-point gasoline.

H. L. HORNING:—Satisfactory results have been obtained in our experimental work with "doped" fuel.

UNITED STATES AIR MAIL SURVEY FLIGHT

AN exhaustive report of the United States Air Mail Survey Flight from New York to San Francisco undertaken by the Post Office Department July 29-Aug. 8, which has been prepared by one of the fliers, Lieut. S. C. Eaton, presents a number of interesting details. When it became known that the flight was contemplated, John M. Larsen, who was importing from Germany Junkers all-metal monoplanes equipped with the B. M. W. 185-hp. engine, offered the use of two of these planes and the services of his pilots at his own expense. This offer the Air Mail Service was glad to accept, by reason of its own limited appropriations, and explains the prominence gained by the J. L. 6 in this country, shortly after Bertram Acosta, flying one of these planes, made the American non-stop cross-country record flight from Omaha, Neb., to a point near Lancaster, Pa., a distance of 1090 miles.

The route selected was, practically, the one traversed by the Army Air Service Transcontinental Flight of 1919. In addition to the two planes offered by Mr. Larsen, the Army Air Service cooperated with the Post Office Department by sending along a J. L. 6 which it proposed to use for fire-patrol duty near San Francisco.

The personnel of the flight, at its take-off from New York were:

Post Office Plane No. 1—Pilot Bertram Acosta, former Curtiss test pilot; Mechanic Ernest Buhl, former B. M. W. factory expert.

Post Office Plane No. 2—Pilot Emil Mons, former German Junkers test pilot; Second Pilot Harold T. Lewis, Air Mail Service.

U. S. Air Service Plane No. 3—Pilot Capt. H. E. Hartney; Second Pilot Lieut. Charles Colt.

Upon reaching the first stop, Cleveland, it was deemed inadvisable to carry the German pilot on plane No. 2, and a telephone request was made to the New York office for pilot S. C. Eaton, who was employed as one of Mr. Larsen's test pilots, to take his place, and to bring along mechanic Charles Myhers to replace mechanic Ernest Buhl.

The passengers were: L. L. Lent, general superintendent of Air Mail Service; John M. Larsen, president J. L. Aircraft Corporation; E. E. Allyne, president Aluminum Manufactures, Inc., Cleveland; Eddie Rickenbacher, former captain Air Service, overseas, and J. A. Bockhurst, motion picture camera man, International Film Service Corporation.

The following control stops were provided and made use of:

Control Stop	*Height above Sea Level, ft.*	*Distance Between Stops, miles*
Mineola	106	
Cleveland	603	503
Chicago	593	307
Omaha	1,034	431
Cheyenne	6,062	455
Salt Lake City	4,248	387
Reno	449	431
San Francisco	15	187

The total mileage was 2,701, one detour being made, namely between Omaha and Cheyenne, to North Platte. The maps carried were an Air Service transcontinental map, a Post Office map, together with Rand & McNally maps of each State traversed.

Supplies requested at each stop were 200 gal. 90-per cent benzol; 200 gal. high-test gasoline; 50 gal. specification 35-35 oil.

The list of spares actually used was

Cleveland—Plane No. 1, several rocker-arms from Plane No. 3. Plane No. 3, washed out of flight and substitute flown to Cleveland from New York to continue flight as Plane No. 3.

Omaha—Plane No. 3, new wheel.

Cheyenne—Plane No. 2, new tire.

Reno—Plane No. 1, broken landing-gear; strut repaired by machine shop. Plane No. 1, one new tire.

San Francisco—Plane No. 2, new exhaust-valve spring. —Air Service News Letter.

The Design Requirements of Commercial Aviation

By Grover C. Loening[1]

Annual Meeting Paper *Illustrated with* Photographs and Drawings

THE general expectations for aviation progress that are voiced by the press and many technical journals, and in discussions among aeronautical people, consist largely of hopes, predictions and an apparently fervent desire for many radical departures. For no other reason than a lack of patience, the public seems dissatisfied with aviation unless it is constantly confronted with some exciting revolutionary step, usually widely advertised as the final solution of practical aviation. The past year gives one particularly glaring instance of this in the entirely unwarranted prominence given to the "all-metal" airplane, and the innumerable editorial comments and other predictions usually made by people unfamiliar with aviation on how this development had solved the "problem."

Many of us must admit that we do not really know what the "problem" is. Aviation problems, like the battle of Jutland, still are being fought out in considerable of a fog. But when the metal airplanes burned up as readily as any other machines and showed many other important disadvantages, sentiment turned too quickly. For example, a prominent New York business man commented upon this development to the effect that, since metal airplanes had been proven unsafe, what was there left that aviation engineers could do. As a matter of fact, the difficulties encountered in the Junkers type of monoplane have, in my opinion, led to a situation where many of its very desirable advantages having nothing to do with its metal construction have been completely overlooked. I particularly refer to the excellence of its engine and its aerodynamic qualities.

There are many such instances in the progress of aviation in which an unexpected realization of a radical departure leads to a full swing of the pendulum which, however, is only short-lived; for, when this radical departure suddenly is found to have been more or less unwarranted, the pendulum sweeps completely the other way to a keen sense of disappointment. Both extremes are wrong; the departure usually has some merit and teaches a valuable lesson. The story of the automatic stabilizer is a pertinent instance of this; four or five years ago it also had solved the "problem." Editorials predicted how the sky would be black with airplanes a few months after the automatic stabilizer had been perfected. A few people then had the temerity to point out that until the automatic stabilizer had become an automatic "lander," it had no real value, particularly as it was rightly expected that the control and inherent stability of airplanes would improve greatly. On the other hand, the automatic stabilizer has a very definite

The Siemens-Schuckert Bombing Plane Equipped with a Central Powerplant Consisting of Six 300-hp. Basse and Selve Engines

[1]M. S. A. E.—Loening Aeronautical Engineering Corporation, New York.

A Bristol Single-Engine Biplane

and valuable use in connection with military aviation, particularly in bombing and navigating, although that is not the one for which it was originally intended. But, few automatic stabilizers are in use today commercially.

Because of the exaggeration of what these new departures will do at the start and the subsequent slump when they fail to meet their expected success, general appreciation by the public that successful aviation is here is tremendously damaged. If the public believes that aviation is impractical and unsafe as a general proposition, it is for the reason that it has been consistently educated to this point of view by aviation people themselves in their over-optimistic statements of what they think they can do. A plea for conservatism is realized now as being necessary to the successful prosecution of aviation. We must prove to the business man that we realize the time has come in the development of this art to stop "rainbow chasing." That is not only typical of commercial aviation, but it is even more evident in military and naval aviation; tactics are frequently evolved first and airplane constructors then are required to invent means of meeting them. The more practical basis would be to take what airplanes have been developed successfully and invent new kinds of tactics to make use of them. Tactics are easier to invent than airplanes.

Misdirected Aviation Development

On the basis of the experience we have had in the past two years the outstanding false leads that appear to have misdirected commercial aviation are as follows:

(1) The supposed advantage of huge multi-engined machines
(2) The unwarranted desire for slow-speed "buses" and slow landing
(3) The impractical applicability of war airplanes
(4) The unwarranted conception of the necessity of "all-metal" construction
(5) The mistaken thought that war aviation helped commercial aviation
(6) The too ambitious efforts to fly over bad country, and overselling

The arguments for multi-engined machines are

The DH 18 Equipped with One Napier Engine

THE WESTLAND LIMOUSINE AIRPLANE

generally known to all; if one engine stops, the other is supposed to keep the airplane going. As a matter of fact, in twin-engined machines having the engines out on the wings it has been found in the mail service that one of the most serious detriments to this type is that the engines stop nowadays more frequently from other causes than individual engine failure. For example, snow and frost on the engines disable both powerplants at the same time.

The use of multi-engined machines, in Europe, in comparison with single-engined machines, has disclosed no advantage. It has disclosed the serious fact that the machines are naturally larger, heavier and more cumbersome to handle on a field and much more expensive to operate. These difficulties are admittedly not as important in the large flying boat but, contrary to what was expected, all over the world the majority of new developments of commercial airplanes are single-engined machines. Obviously, the correct basis for consideration of this question is that presented by Frank Searle, who manages a London to Paris air line. He states that from the standpoint of reliability two engines are not better than one, simply because the one engine must be made absolutely reliable. Besides this, there is a totally mistaken idea in the mind of the public as to what causes engine failures on airplanes. It is very rare that the engine itself actually fails. Usually something fails in the gas line, a water line, or the like; so, the simpler and more direct installation of a single-engined unit is very advantageous.

From the standpoint of expense in maintenance, which constitutes the big charge in running an air transport line, where the big multi-engined machines require 15 to 20 men as a ground crew to handle them, three or four of these men could handle in the same time as many single-engined machines as there are engines in the big machine. It must be admitted also that the most expensive part of an airplane is the engine. The engine and its installation have always been, in the experience of many, the major cause of expense in maintenance work. In looking into the desirability of these large airplanes as compared with smaller and simpler ones, we should examine the very pertinent point as to the useful load carried per-engine.

A BRISTOL TRIPLANE EQUIPPED WITH FOUR ENGINES

TABLE I.—USEFUL LOADS IN SINGLE AND TWIN-ENGINED AIRPLANES

Type	Single Engine	Twin Engines	Size, hp.	Weight Empty Including Water, lb.	Useful Load at about 9 Lb. per Sq. Ft., lb.	High Speed, m.p.h.	Useful Load per Horse-power Including Fuel, lb.
Fokker, V-45	185 B.M.W.	.....	250	2,640	1,540	93	6.15
Avro Triplane	Six-cylinder Siddeley	.....	245	2,460	1,220	96	4.97
Bristol Biplane	Six-cylinder Siddeley	.....	245	2,650	940	108	3.84
Westland, 6-seater	Napier Lion	.....	450	3,823	1,736	118	3.85
Central Aircraft	.....	Beardmore	354	4,996	2,250	89	6.30
Vickers, "Commercial"	.....	Rolls-Royce	700	7,790	3,267	103	4.68
Martin, "Transport" at 9 lb. per sq. ft. of surface	.....	Liberty	800	6,800	3,289	110	4.10
Handley-Page, W8	.....	Napier Lion	900	7,850	3,593	119	3.98

Table 1 presents a few figures on single and twin-engined aircraft; it is not in any way comprehensive, but indicates a very interesting result. In addition to the usual figures that have been given, a quantity entitled "useful load per horsepower" has been derived. It will be seen that even though the single-engined machines are largely related to war styles, with needlessly high safety factors, the fact remains that single-engined machines differ very slightly from multi-engined machines, all of those machines making about 110 m.p.h. and carrying somewhat around 4 lb. per hp. of useful load. The figures differ, of course, with the slower machine. For example: for the Fokker V 45, which is slower than many of the others cited, the figures at least show that any claim for a tremendously greater efficiency for multi-engined machines in carrying useful loads is entirely unwarranted.

A question then arises from a practical standpoint. Given the expense of 100 engines would a commercial aviation company have a more flexible organization and be less liable to loss by crashes if these 100 engines are distributed to 100 smaller airplanes or 25 larger airplanes; the net tonnage carried per year being the same, but the number of pilots naturally being increased? I believe the latter increased expense is offset very quickly by the fact that the smaller ground crews required for the single-engined machines would be kept busy all the time handling one single-engined machine after another; whereas the much larger ground crew required to handle the larger machines cannot be kept so busy and must of necessity be waiting for the arrival, departure or repair of the fewer large units. We can at least conclude that the much advertised solution of commercial aviation by the use of large machines has not materialized, and that the use of these machines has, in fact, raised a very serious question as to whether they are anywhere near as cheap to operate as the smaller units.

Regarding slow speed and slow landing, a paper was presented before the Society two years ago in which it was maintained that the raison d'être of aviation is speed. This continues to be the case, but at that time there was considerable argument to the effect that what aviation needed was not speed, but slow-speed "buses" that would lumber along in some old-fashioned way and were supposed to be desirable because they would be safer when landing. Slow speed does not always increase the safety of landing. This is particularly true of a machine that is very clean in design and speeds up fairly fast on a glide. If it is endowed with a low wing-loading in an effort to get a slow landing, it is likely to float interminably before it will actually stop rolling. To make slow landings high head resistance and low diving speed are needed, because the portion of a landing maneuver that uses up a field is the coasting of the airplane right near the ground, during the interval when it is endeavoring to stop flying and stick to the ground. At any rate, developments of recent machines have shown that a landing speed of 60 m.p.h. can be handled in a reasonable field, providing the machine slows up quickly after its wheels touch.

It is generally accepted now that the war types of airplane are not commercially applicable as easily as was expected. The airplane structure part of these machines is built with a much higher safety factor than is needed for commercial use. This involves an increase in weight that is distinctly uneconomical for commercial flying. Airplanes of one-half the safety factor of most war machines could be flown with safety. War-type machines were not in any way designed with a view to weathering qualities and, particularly on those types of machine on which veneer is used in the engine bed, where this is likely to get soaked with oil, and where small fussy parts requiring adjustment are hidden away in the fuselage and threads of too fine a pitch are easily crossed when roughly handled, the commercial airplane company runs into expenses in upkeep that are entirely unwarranted and which before long more than make up for the original lower price of the machine.

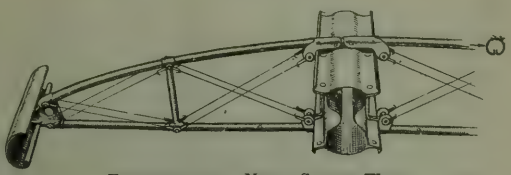
The smaller types of war machine do not carry enough load to make their expense seriously worth-while; the big machines are expensive, difficult to handle on a field and require expensive hangars. There are some types of naval flying boat that have been found distinctly useful, but principally because they require less alteration from a commercial standpoint in their installations. In the construction of war types of airplane, practically no thought was given to the protection of passengers and, above all, to the reduction of noise. Both of these features become of very great importance in commercial aviation, particularly the latter.

Are the engines used in war airplanes actually of a type at all suitable for commercial aviation? The lack of a muffler is by no means the most serious defect. The engines have generally such high compression that they bring with them endless spark-plug troubles. They are hard to start, difficult to cool and, particularly, full of minor carbureter and ignition difficulties. Many of their vital parts, such as the carbureter on the Liberty engine, are highly inaccessible locations and in many cases very dangerous from the standpoint of fire. The engines are in no sense commercial and were never designed as such. They, furthermore, possess several features calculated to

give performance at great altitudes. These features are not useless by any means, but are certainly not fundamentals that must be met in commercial aviation.

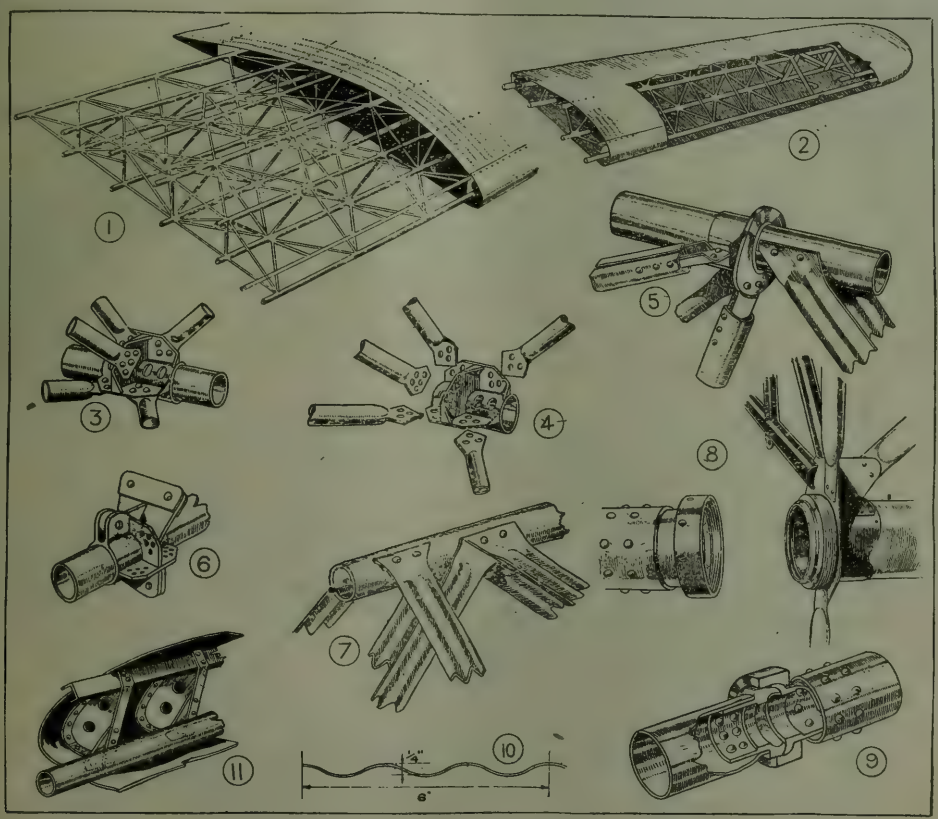
The most important feature that causes difficulties in using war airplanes commercially is the generally amateurish and inaccessible installation of the powerplant. Vital gas lines, filters and connections are generally hidden in out-of-the-way places; they are hard to see and in many instances difficult to replace. The reason for this is merely lack of development; the time for the production of a machine was short and these innumerable small details did not have the commanding importance on a war airplane that they have in commercial work. Constructors the world over have realized the inapplicability of war airplane types, and are busy designing new ones.

There has been much cry about "all-metal" construction and, opposed to this, considerable talk about "all-wood" construction. There is only one kind of construction that is really correct for an airplane; it is an "all-simple" construction, whether it be of wood, metal, paper or rubber. One false lead that has deceived many people is that metal construction is easier on quantity production than any other type. Based on con-



FRAMEWORK OF A METAL COVERED WING

siderable experience in this kind of work, I venture to state that there is no more difficult type of construction for production in the small quantities in which airplanes are built than in metal, particularly "all-metal." The styles in airplanes, the load to be carried and the engines used, vary entirely too quickly to warrant the extremely expensive jigs and fixed equipment of tools needed to make metal construction economical. In addition, we have the serious situation today that metals are actually very hard to obtain, particularly in the light gages used on airplanes. This applies not only to duralumin, but to many grades of steel and steel tubing. But there are very notable instances in the details of airplane con-



SOME CONSTRUCTIONAL DETAILS OF THE JUNKER WING

1 and 2—General Construction of the Wing; 3 to 7—Details of Wing Braces; 8 and 9—Details of Wing Attachment; 10—Details of Corrugated Sheet Covering; 11—Detail of Leading Edge

struction in which the use of metal is apt to bring with it great simplification without increasing weight, and in almost every case this usually can be found in some part where a complicated metal fitting may be needed to take hold of a piece of wood. It is well known that the metal fittings are the expensive part of wooden airplane construction. When the wooden construction becomes more and more simplified, eliminating the number of small fittings, the necessity of metal construction becomes less urgent. It is possible to foresee in the general trend of development that the solution is a very judicious combination of the two, already reached in some new types of commercial airplane that have steel-tube fuselages and wooden wings.

One of the general arguments presented in favor of metal construction is the increased weathering qualities

A Linen Covered Wing Made with a Steel Framework

to be obtained. This is distinctly a false lead. The deterioration of linen-covered wings is not at all great on the linen itself; evidence of this can be found in the experience of the United States Navy, which has kept a squadron of large twin-engined flying boats absolutely out in the open at sea without very serious damage, for months at a time. What deteriorates in this construction is not the linen so much as the light glued veneer parts inside the wing. When strained these are likely to open seams, thus letting in the weathering and gradually disintegrating the structure.

There is ample indication that, given proper wooden construction on the inside of wings, with all the parts large and solid and few in number, a linen-covered wing will have plenty of durability for commercial purposes, with a veneer-covered wing a close second. It cannot be said that the veneer-covered wing is superior to the linen, when the ease with which the linen can be replaced in perfect order every few months is considered.

As for the metal covering of wings, what work has been done along this line has shown that the gages of the metal are so light that an extended use of the machine soon starts it cracking at the seams. The rivets pull out of the thin metal. The result is that after extended flights one can shake a handful of rivets out of the all-metal wing. The entire structure when built of metal is rigid, which is exactly the condition that is not desired on a metal frame in an airplane, because, as it is, the vibrations of the engine are harmful enough in their crystallization influence. But when a metal framework is covered with linen, the linen supplies exactly that quality of deadening shock which is greatly to be desired and likely to extend enormously the resistance of the metal frame to crystallization.

It seems possible to conclude from a general survey of standard practice at the present time that it is distinctly desirable to build fuselages of steel tubing, and particularly safe to do so around the pilots and passengers because, in the event of a crash, the fuselage members will buckle without splintering. Furthermore, it is found that for the same strength a metal-frame wing, linen covered, is heavier than a wooden frame, linen covered, by so large a margin as not yet to have justified itself. Many other parts of the machine, such as the landing chassis and the engine-bed, have for a long time been built of metal on various machines with entire success. The framework of rudders and fins on a large majority of airplanes have been built of steel tubing for years, so that there is nothing particularly new in a partially metal construction and absolutely no conclusive reason for abandoning linen as a covering material. New methods of doping have made linen much more weatherproof, but when we add to that more recent developments in making this covering absolutely fireproof, it is likely to come back into its own as a remarkably strong and useful material, apt to survive as long as canvas does in sail-boats.

What is actually needed in the development of construction details is merely intelligent simplification of parts. This refinement is obtained only by patient effort year after year in improvements. I ran across a 1908 type of airplane recently. When I saw the hundreds of different little fittings, gadgets and turnbuckles, no two of which were alike, innumerable different sizes of wires, etc., I had a very keen appreciation of how greatly airplane construction has advanced.

Influence of War Aviation

One hears much about the great number of years of progress the four years of war contributed to aviation. Such statements are surely made without a sincere study of the subject. In my opinion, war aviation hindered the development of commercial aviation for just that particular period and did still greater harm. It caused thousands of our young men to think of aviation in the terms of the battle front, where the disagreeable features of air fighting and that particular type of professional use of the airplane gave them an entirely different viewpoint than is needed for the stimulation of the use of the airplane as a pleasure vehicle. I know dozens of former war pilots who see no future advantage in flying. They cannot see that commercial peace-time flying will be entirely different.

During the war the details of construction that developed in simplification would, I believe, have developed more rapidly and with a more direct bearing upon commercial aviation, had there not been that tremendous military urgency, making it necessary for designers to compromise in innumerable instances upon the ready at hand 50 per cent correct detail, which would work well enough, in place of the ideal which they would have sought had they not been pressed for quick results by the greater emergency. For example, the simplest detail in an airplane is the seat; but in war airplanes today there is no really comfortable seat and certainly nothing that has had put into it the thought that has been put into seats in automobiles. From a war-airplane standpoint this is correct. From a peace-time standpoint the ignoring of such details is obviously wrong.

Since the war there has been great progress in working out some of these details required for the commercially successful airplanes. A survey of the progress that has been made in the last two years shows where we

THREE-QUARTER FRONT VIEW OF THE FOKKER PLANE

would have been three or four years ago in commercial aviation had we not devoted our energies to the military side. It is unfortunate if, as maintained here, with all the money spent during the war commercial aviation was not greatly benefited; but a review of the conditions serves to bring out some of the distinctions between military and commercial aviation more clearly.

One of the results of the feverish influence of the enormous aviation activity during the war was to start a commercial aviation campaign of overselling, which threatened to wreck the whole industry. Because thousands of airplanes had flown over the battle front, of course it followed, in the minds of many people, that thousands of airplanes would immediately fly over the cities. The expected result failed to materialize, whereupon aviation was pronounced impractical by many. As a matter of fact, between these two extremes the really sound use of airplanes here and there in an entirely practical way that is possible and would, if followed, lead to a thoroughly solid, conservative development, was rather swamped in the rest of the noise. As a corollary of this state of affairs, many attempts at great flying demonstrations were carried out over bad country and, therefore, accompanied by serious accidents. A year of this, in which the number of fatal accidents was great, is taking years of patient effort to efface and, as stimulating public interest and helping the aviation business, it was devoid of helpful results. In other words, it would be far better for the aviation industry to go all the way to the other extreme and never fly unless a safe performance were absolutely certain.

How beneficial such policy can be was shown by the change in the plans for the Pulitzer race. It was originally intended to fly across the continent, in a manner that would not have permitted proper organization of flying fields for safety, and presumably would have resulted in many serious crashes. Instead, it was very wisely decided by the Aero Club of America to hold the race over a short circuit of flying fields situated on Long Island, an ideal flying race-course. The result was that, with about a dozen machines coming down in forced landings, there was not a single serious accident. The reason was that practically all of these machines landed on flying fields, or on fields that permitted of reasonably safe landing. There was a very wide-spread realization, on the part of a vast multitude of people who had seen

THE VICKERS-VIMY COMMERCIAL AIRPLANE

the race, of the fact that after all aviation is not so dangerous, and this was expressed in editorials in papers throughout the country. The dangers were exactly the same as in any other race, but disaster was not courted as it had been theretofore.

Questionable Future Developments

The future developments spoken of at present which possibly are apt further to mislead commercial aviation can be considered briefly.

(1) Are the higher-powered engines, that many are interested in, being developed along the right lines
(2) Is the introduction of complications, such as variable camber and retractable running-gear, really necessary
(3) Are the new "high-lift" wings so important
(4) Is an "aerial tramp" desirable

Commercial experience to date seems to indicate that higher power is not needed as much as greater reliability. The loads on commercial machines are becoming so high in proportion to the weight of the engine that the advantage of the retractable feature will become almost negligible. In other words, is it not likely that simplicity and refinement of what we have will give a neater landing-gear of fewer parts and perhaps less weight, as against taking our present clumsy landing-gear, admitting its clumsiness to be unavoidable, and adding the complication of hoisting it into the body? For a small racing machine the landing-gear saving is of much higher proportionate value, due to the small size and weight of the airplane.

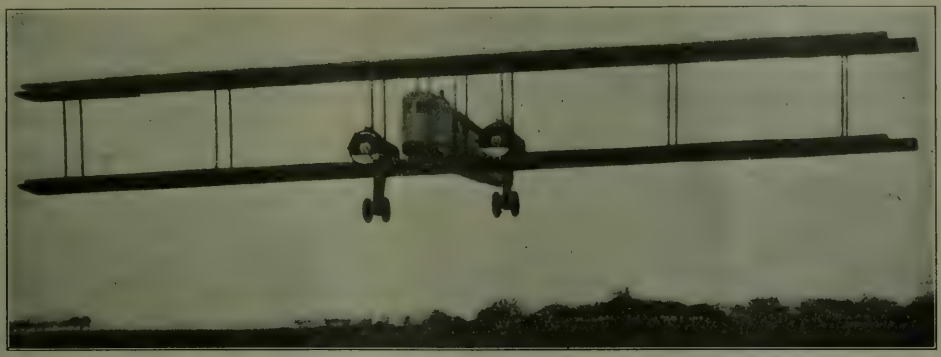
Concerning the new "high-lift" wings, we hear much today about various wings guaranteed to give enormous lift, the statements being accompanied as usual by prediction that our old friend the "problem" has been solved. In none of the data presented on these high-lift wings, such as those for the Handley-Page, are any figures given as to the increased weight of the airplane, due to the much greater weight of the wing structure, which will very likely be found necessary to make these new types of wing as strong mechanically as the present ones and capable of being operated in the air. I venture to predict

The Handley-Page W8 Airplane Propelled by Two Napier Engines

that 100 lb. more or less is not a serious difference and can very well be afforded if increased reliability can be obtained thereby. It seems that new ideas in engines are not as requisite as consistent perfection in the details of what we have, I mean details of installation that are admittedly bad and could be made better if the engine were simpler to install.

A slight increase in speed is obtainable by drawing the running gear up into the body and by flattening out the camber, but a point to bear in mind is that variable camber does not give higher lift than a "high-lift" wing-section. The point is difficult of argument in the abstract. The innovation is undoubtedly worth trying but, as in the case of many other things on airplanes, to justify itself the complication will have to show far greater advantage than it seems it will show. It is not likely that with the engines available commercial airplanes will run much over 120 m.p.h.; so, let us examine a landing-gear representing a total head resistance of approximately 57 lb. at this speed on a 5000-lb. airplane of 400 hp. Without any increase in weight, the retractable feature would reduce the head resistance by this amount and cause the machine to speed up 2.3 m.p.h. But if the head-resistance of the landing-gear itself is halved by modified and more careful design, it is obvious that 50 per cent or more of the increased lift claimed will be used up in the load added to the dead-weight of the airplane, due to a heavier structure. Certainly, one thing must be admitted; any such complicated construction will be more expensive and require more maintenance. Here again we see a false lead, perhaps swamping a sensible development, that is to take our present wing structure and modify the curves themselves so as to get a high-lift wing-section. This is being done already by many constructors, and incidentally in many cases with marked success. It still appears possible to modify the curve of the rib and gradually improve the depth of the wing for ample spar room, without any serious increase in the resistance and yet with a higher and higher value to the lifting coefficient. Development in this way will follow closely the same trend as the development of the lines of hulls of boats followed, resulting in gradually decreasing their resistance per horsepower for a given buoyancy.

By "aerial tramp" is meant a slow load-carrier. It is almost certain that airplanes will be load-carriers. But, will they be slow? The whole idea of using them to carry loads is to exceed the speed of a train or boat; warranting the higher expense. We should look forward to the time when high-class express and passenger traffic



THE FARMAN GOLIATH AIRPLANE

will be carried by air, with the railroads devoting themselves to the heavy freight about which there is no great hurry. The competition in load-carrying can be expected to be keen, particularly when it is realized how long cheap freight haulage has maintained its volume of business against the express. Apparently there is a minimum load for a commercial airplane; namely, eight or ten passengers, or 1000 to 2000 lb. of goods. Since the entire object of commercial aviation is to provide transportation at high speed, is it not likely that the development will be along the lines of carrying this load at higher and higher speed, rather than more and more load at the same speed?

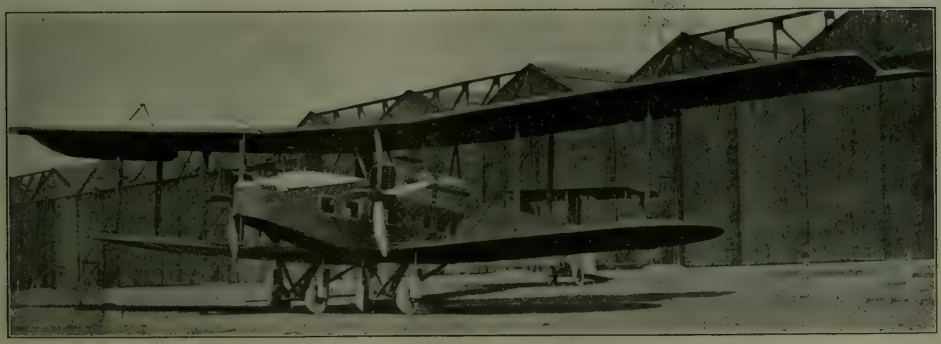
DESIRABLE FUTURE DEVELOPMENTS

Among the modifications to airplanes that can be looked forward to as highly desirable and much needed for the advancement of commercial aviation is durability of construction. In this should be included the reliability of operation of the engine as the foremost necessity. Mention has already been made of the fact that increased durability of the structure of the airplane itself, is apparently obtainable by simplification when wood is used, and by the use of steel tubing in the fuselage and other parts such as the control surfaces and landing-gear. In the wooden construction there must be eliminated the fussy glued-up parts, tacked together with pieces of veneer which, when they soak up water, begin so readily to open seams, or when stored for a long time not only warp but in many instances because of the peculiar glue used start a deteriorating sort of fungus growth. A good healthy piece of wood will last as long on an airplane as on a boat and, taken hold of by a simple and accessible metal fitting, can be expected to give ample durability. Then, too, in the interest of durability, airplanes should receive some care. Is it too much, for example, to ask that they receive the same care as yachts or high-class motor cars receive? It is shocking to see the condition of some commercially used airplanes; one marvels not at their lack of durability but that they can be flown. As long as the delicate part of the airplane, the engine, needs the attention which it certainly must have, it is not a difficult matter to clean and polish the structural parts of a machine. Our present construction, therefore, with a little more steel framing used, with the wooden parts few in number and made large and solid, and, above all, with the construction accessible for inspection and cleaning, appears to offer plenty of durability for commercial purposes.

There are many desirable features to be looked for in the development of the powerplant; for example

(1) Muffling devices to deaden the noise of the engine
(2) Gearing, or geared-down engines or, better still, slower running engines to improve the propeller horsepower by increased efficiency, particularly at getting-off speeds and climbing speeds
(3) Further development of the reversible-pitch propeller
(4) Finally, the development of what now seems to be an ideal airplane engine

The necessity of mufflers need hardly be dwelt upon, because there is nothing more disagreeable or that robs



THE HANDLEY-PAGE 0-400, A WAR TYPE OF AIRPLANE WHICH HAS BEEN MODIFIED FOR AIR TRANSPORT

flying of more of its charm than the incessant noise of the engine, this being the cause of a nervous strain that unconsciously makes people dislike flying without exactly knowing why. An ordinary motor-car muffler may not be readily applicable to an airplane engine, due to the enormous volume of gases that has to be handled as compared with the lower-powered motor-car engines, but the exhaust of an engine has an energy, the firing off of which into the air can be delayed by many means, and can even be made useful in deriving some slight additional power or, as in the case of some superchargers, in driving a mechanism for some other purpose. Next year, after some of the new developments on the muffling of airplane engines shall have been more fully worked out, we may find that this problem will have been solved in an efficient manner involving relatively little weight.

The use of gearing is a difficult matter; that is, the gears must be pretty tough to stand it. The big problem appears to be the heat transfer. The loss of power in the gears is represented largely by heat. In the high-powered engines this means that an enormous quantity of heat must be taken away from the gears. Various oil-cooling devices have been experimented with. Some of them work, but the weight of the gearing is still high, ranging from 1 to 1½ lb. per hp. A detail like this, however, can be developed only by persistent hard work in eliminating defects. Many people are working with this in view, particularly in Europe. The ultimate aim is, of course, to derive an airplane with an engine-room such as one has on a boat, with the engine accessible at all times and permitting minor repairs during the flight. It is not easy to state whether gearing justifies itself, for the simple reason that really successful gearing has yet to be developed.

The reversible-pitch propeller will probably make it possible to land an 80 m.p.h. landing speed airplane in the space where a 40 m.p.h. machine lands today. Conversely, due to the variation in pitch available, there is a higher thrust at slower air speeds thus offering more power for acceleration and therefore giving a quicker get-away and climb for getting out of small fields with a fast machine. It is very convincing to see an airplane with a reversible-pitch propeller come down for landing in a normal manner and, just after wheels make contact with the ground, when the long roll to the other side of the field begins, observe the reversible-pitch propeller come into play and slow the machine up quickly.

To put down in specifications what would be an ideal aviation engine for commercial purposes is almost impossible in the present state of the art. We have an S. A. E. committee in the proceedings of which it is ruled that if two aeronautical engineers actually agree on any one point, the verdict concerning it becomes unanimous. In other words, every designer seems to have his own favorite hobby. Some features, however, can be stated as covered by considerable agreement among constructors and operators of airplanes. For example, the simplest smoothest-running engine is a six-cylinder vertical. It is narrow and has comparatively low head-resistance and its length is not serious in a commercial machine. It is simple and accessible. But the trouble with our present six-cylinder types of engine is that they are either too low-powered or operate at too high a speed. If the airplane designer could have a 300-hp. engine turning at 1000 to 1200 r.p.m. he would have not only a higher propeller efficiency without gearing, but the slower engine speed would make the use of a reversible-pitch mechanism easier and the propeller less noisy.

Some constructors are greatly in favor of very high-powered engines, but there is fairly general agreement that for a commercial airplane at least 300 hp. is necessary. The advantages of gravity feed for the fuel are obvious, so the ideal engine must have its carbureter low, facilitating gravity feed. Whether battery ignition or magneto ignition is used does not bother the airplane man very much, except that with battery ignition it apparently becomes slightly more economical to install an electric starter, which is much to be desired. But the spark-plugs must be in a position where they can be removed very readily, and the ignition parts must be so placed that they can be protected from dampness and readily opened up and cleaned. The carbureter must have a far healthier and larger filter than any of them has at present. No matter how careful one is with fuel lines, there is always the possibility of dirt getting down to the carbureter, with the consequent danger of clogging the needle-valve. The ideal airplane engine for commercial purposes should also carry its oil and all the connections that have to do with it in the engine, and have incorporated in its design a centrifugal oil-cleaner.

The engine, as already pointed out, must be equipped with mufflers. Furthermore, when we consider the radiation system, which has been a bete-noir by actual statistics, on over 85 per cent of the airplane types developed to date, we find incompetent work on the part of airplane and engine people alike. The fact of the matter is that many of the faulty radiation systems that exist are faulty only because they have really never been tested properly. The engines are run through their endurance test of 50 hr., but with a water barrel holding perhaps 25 gal. of water, many feet above the top of the engine, giving a condition of circulation in the engine that is not at all similar to that of the airplane's system. When 50-hr. tests are made on a powerplant in the future they should be made on a complete powerplant, in which the radiation system, as actually intended to be used, is considered fully as important as any other item. As a matter of fact, there is considerable question as to where the design of the radiator and its connections should be left to the airplane constructor to work out.

Given an engine of the above characteristics with its six big cylinders, the airplane designer can afford to offer to use this engine with considerable enthusiasm, even if its weight for 300 hp. is as high as 1400 lb., or twice the weight of present 300-hp. engines. With an engine of this weight it would be possible to fly a 5000-lb. airplane at well over 100 m. p. h., carrying at least 1500 lb. of useful load. The sacrifice of a passenger or two, due to the heavier weight of the engine, is a minor matter compared to the increased reliability that it would be possible to obtain with the heavier weight-allowance. Furthermore, there is even a more important consideration in that the heavier engine will be very much cheaper to build and not require extraordinarily fine materials.

In conclusion, is it not possible in a resume of design characteristics and requirements for commercial aviation to place many developments in their proper category by emphasizing that all-metal construction is a secondary need, a gradual development in itself already resulting in partially metal construction; that in structural features what is needed is great simplicity and refinement in the reduction of the number of parts and fittings, whereas in the engine and installation we have simply to go along our present lines a little more consistently and patiently to obtain that element of reliability which is more important than any other element in connection with airplane construction.

The Volatility of Internal-Combustion Engine Gasoline

By Frank A. Howard[1]

Annual Meeting Paper *Illustrated with* Drawing

THE meaning of the term "gasoline" seems to be generally misunderstood for the reason that it is assumed that gasoline is, or ought to be, the name of a specific product. It is not and never has been a specific product; whether it can be, or should be, I shall leave to your judgment.

Gasoline has a definite and fixed generic meaning in the oil trade, but no specific meaning whatever. It means merely a light distillate from crude petroleum. Its degree of lightness, from what petroleum it is distilled and how it is distilled or refined are unspecified. It may not be known generally that practically every grade of distillate which was ever popularly known as gasoline is still made and sold. It is not sold as gasoline, but is distributed under its specific trade or technical name, such as "76 naphtha," "66 naphtha," "P C naphtha," or something else. Such sales are only at wholesale or on a contract basis as a rule, not through the retail bulk distribution systems for engine fuel. No product of the nature of gasoline can be economically distributed at retail in bulk unless there is a large and constant demand. This is our clue to the only specific meaning of the word gasoline. Specifically, "gasoline" is the particular grade of gasoline which at a given moment is distributed in bulk at retail. I think it can be defined with reasonable precision as being the cheapest petroleum product acceptable for universal use as a fuel in the prevailing type of internal-combustion engine. I emphasize the three factors of this definition: (*a*) the cheapest product, (*b*) its universal use and (*c*) the prevailing type of internal-combustion engine.

So long as there is any such thing as a single prevailing type of engine and so long as there is substantial unanimity of view as to the acceptability of any single grade of product in this engine, the definition I have given is practically an axiom. This has been the condition up to the present time, and it is in some ways an ideal one. On this point, however, I am holding no brief. My sole purpose in this discussion is to clear away, if possible, some of the haze which surrounds the word "gasoline." If I have helped to make clear the fact that gasoline in the specific sense in which it is used does not purport to be a fixed product, but only the official title of the successful bidder for popular patronage in the engine-fuel market, my purpose will have been served. Until we have a Volstead act on engine fuels, prohibiting the manufacture and sale of any hydrocarbon product containing more than ½ of 1 per cent boiling above 300 deg. fahr., unless denatured with a sufficient quantity of carbon tetrachlorid or other approved fire extinguisher to make it poisonous to any misguided engine which may attempt to use it internally, I do not see how we are to prevent some enterprising refiner from offering to the public an engine fuel different from that which has been previously sold as gasoline. If it gives more service at lower cost than the competitive products, I do not see how we are to keep the public from buying it or prevent the public from continuing to call it "gasoline" if so minded.

I shall try to tell what volatility is with reference to engine gasoline. The prevailing type of engine up to this time has been essentially a gas engine, an engine which consumed its fuel in the form of a gas. The two prime requisites of the gasoline are, therefore, that it be a fuel, and that it be capable of conversion into a gas. So far as I know, no one has yet questioned the fact that gasoline is a fuel, but there seems to be a widespread conviction that it cannot be gotten into the cylinders in the form of a gas. This low volatility of gasoline, and its volatility is low, is the root of most of the trouble which is being and will be met with. My purpose is to show how much of the difficulty is inherent in the fuel and how much of it arises from the failure of automotive engineers, collectively, to attain a high average of perfection in the handling of the fuel. This is not a criticism. Among engineers, at least, I think it safe to refer to an engine as 10 per cent or 50 per cent efficient, without the deduction being drawn that the responsible persons are being haled before the bar of public opinion for their 90 per cent or 50 per cent of shortcomings.

Ordinary engine gasoline of the grade now sold possesses sufficient inherent volatility to take and maintain the condition of a gas at a temperature at or below average intake-manifold temperatures. Manifold condensation seldom, if ever, occurs and cylinder condensation is even less probable. The phenomena answering to these names are in fact mainly the visual evidences of the failure of the vaporizing device to function. Fuel once vaporized must stay in that condition; hence, if liquid is found beyond the vaporizer, it reached there as a liquid. These conclusions are based on an examination of the fuel itself. Here is the evidence; first chemical, then physical:

Volumetric Proportions of a Combustible Mixture

As a corollary of Avogadro's law, the volumetric proportions of a mixture of gases are represented by their molecular proportions, and these in turn are represented directly, in the case of a gaseous fuel mixed with the proper amount of air for combustion, by the equation of combustion itself. For example:

$$C_5H_{12} + (8O_2 + 32N_2) = 5CO_2 + 6H_2O + 32N_2$$

From the equation it therefore appears that a perfect mixture of pentane gas, or vapor and air, must consist of 40 parts by volume of air made up of 8 parts of oxygen and 32 parts of nitrogen and 1 part by volume of pentane. Pentane is the lightest hydrocarbon found in any substantial amount in gasoline. Again:

$$C_{11}H_{24} + (17O_2 + 68N_2) = 11CO_2 + 12H_2O + 68N_2$$

This shows that a perfect mixture of vaporized un-

[1]M. S. A. E.—Development manager, Standard Oil Co. of New Jersey, New York City.

decane and air comprises 1 part of the fuel and 85 parts of air, by volume. Undecane is probably the heaviest hydrocarbon present in any substantial amount in gasoline.

Since gasoline consists of hydrocarbons lying between these limits, there being more of the lighter than of the heavier, the volumetric proportion of gasoline vapors in a perfect mixture will be somewhere in the neighborhood of 1 part in 60, or 1.67 per cent. It may help us to appreciate this if I say that the air of this room normally contains a proportion of water vapor just about this high. If water were gasoline, we would be living in a substantially perfect combustible mixture most of our lives. If we can visualize this condition, it will be easier to follow the physics of this question.

The boiling point of water at sea level, under a normal barometer, is 212 deg. fahr. Nevertheless, the air of this room contains something between 1 and 3 per cent of water vapor. How did it get here and why does it stay here? It got here by evaporation from the sea and it stays here because it cannot condense. Apparently, therefore, the boiling point of water, or of engine fuel, does not fix the temperature at which it evaporates and stays evaporated. Some other factor must be involved. This factor is the *proportion* of vapor in the air. The boiling point is the temperature at which there is 100 per cent vapor in the air, which is an Irish method of stating the fact. Since automotive engineers are interested in a perfect mixture containing less than 2 per cent of vapors of gasoline, it would appear, therefore, that the boiling point of the gasoline is more a matter of academic interest than a critical measure of its volatility. From an automotive engineering standpoint, the volatility of the gasoline is to be determined by its ability, or lack of ability, to form a stable 1 or 2 per cent mixture with air, and not by its ability to form a 100 per cent cloud of gas pushing the air away ahead of it, which is the phenomenon called boiling. If it is a light gasoline, such as pentane, we want it to be stable up to about 2 per cent; if it is heavy, like undecane, we want it to be stable up to about 1 per cent. From this we draw the interesting conclusion that the lighter the fuel is, the greater its volatility must be to permit it to exist as a stable mixture. Roughly, pentane must have twice the absolute volatility of undecane to be equally volatile from a carburetion standpoint. It actually has more than twice the absolute volatility, but the thing to be borne in mind is that a comparison of absolute volatilities will be very misleading unless read with a combustion equation which fixes the required volatility. The true comparison is the relation of absolute to required volatility of the fuels compared.

Physical Meaning and Measurement of Volatility

The physical laws which govern the volatilization or vaporization of liquids were clearly enunciated by Dalton about a century ago. These laws, or the one law and its corollaries, are generally referred to as Dalton's Laws of Vapor Tension, and can be stated adequately for the purpose of this discussion as follows:

(1) A liquid will continue to evaporate from an exposed surface thereof until there is established on that surface a definite pressure of the vapors of the liquid

(2) This definite pressure changes with the temperature of the liquid, but is independent of the presence, character or quantity of any other gases or vapors existing above the liquid

(3) This definite pressure is called the "vapor tension" or "vapor pressure" of the liquid at that temperature. If the vapors of the liquid are admixed with other vapors or gases, the total pressure of the mixture multiplied by the volumetric percentage of any constituent gives what is plainly named the "partial pressure" of that constituent. So long as this partial pressure of the vapor in question is below the vapor pressure of the liquid at that temperature, condensation cannot occur

The usual method of measuring the volatility or vapor tension of a liquid is to introduce a sealed vial of the liquid into the space above a mercuric barometer column, then to break the vial and read directly the lowering of the barometer which shows the pressure developed by the vapors of the liquid. This, of course, gives the vapor pressure in vacuo, which, according to Dalton's laws, should be the same as that developed in air or in any other gas. Generally this is true, but in the case of gasoline and some other mixed liquids the results obtained differ slightly from measurements made in air. Since we are directly interested in the vapor tension in an atmosphere of air, the form of instrument designed by C. I. Robinson, chief chemist of the Standard Oil Co. of New Jersey, is preferred. This instrument is illustrated in Fig. 1. It consists of a graduated U-tube *a*, one leg of which is surmounted by an air bulb *b* cut off by cocks. The upper one is a two-way cock and this, in turn, is surmounted by a feed reservoir and trap *c*. In using this instrument, both legs of the tube, as well as the reservoir and the trap, are filled with liquid to be measured, leaving the cut-off bulb filled with air. The two legs of the tube are balanced. Liquid is then permitted to drop through the bulb for a few minutes. The upper cock is closed, the legs are balanced again and the increase in the volume of air is read directly on the graduated leg of the tube. The temperature is controlled by immersing the whole instrument in a water bath before and during the measuring.

With this instrument, the absolute volatility of an average 58-deg. Baumé engine gasoline of the present-day grade was determined as follows: First the vapor tension of the original gasoline was determined at two temperatures. Then the sample was reduced by distillation in the ordinary way, taking off successive 10 per cent fractions. After each reduction operation the vapor tension of the residual portion of the gasoline was determined at temperatures of 50, 75, 100 and 125 deg. fahr. Table 1 gives a complete inspection of the original gasoline and Table 2 shows the results of these measurements.

In dealing with a complex liquid such as gasoline, the full interpretation of these results carries us much further into the field of the physical chemist than it is necessary for us to go today. We are dealing specifically with the question of minimum volatility. Is gasoline inherently volatile enough to permit complete vaporization at ordinary manifold temperatures or is it not? Let us, therefore, take the heaviest portion of the gasoline, the last 10 per cent, which we find has a boiling-point range of 380 to 435 deg. fahr. It is this portion which some of you automotive engineers have urged the refiners to cut out, stating that it cannot possibly be vaporized or kept from condensing and is, therefore, not only of no value but actually detrimental to the engine. Returning to our combustion formula we find that if the fuel were composed entirely of this very heaviest fraction, a perfect mixture would contain about 1.2 per cent of fuel vapor. The average pressure in an engine manifold is around 0.5 atmosphere. Calling it 400 mm. of mercury, $0.012 \times 400 = 4.8$ mm.; which is, therefore, the partial

TABLE 1—57.9-DEG. BAUMÉ ENGINE GASOLINE USED FOR VAPOR TENSIONS

Temperature, deg. fahr.	Percentage Off
Start 108	..
122	2
140	4
158	8
176	12
194	17
212	23
221	26
230	29
248	36
266	43
275	47
284	51
302	60
320	68
338	75
356	83
374	88
392	92
410	94
428	96
Final 435	97 Recovered

pressure of fuel vapors, assuming that we have a fuel made up entirely of the least volatile fraction of the present gasoline. We find that at any temperature above 125 deg. fahr. the least volatile portion of the gasoline has a vapor pressure well above 4.8 mm. Our conclusion must be, therefore, that even if the gasoline consisted entirely of what is at present its heaviest constituent, it would still possess sufficient inherent volatility to make it a possible fuel for an engine essentially a gas engine. It is a fuel and can become and must remain a gas at an intake temperature not substantially higher than present practice.

This examination of the volatility of a typical engine gasoline does not represent the whole of the problem by any means, but it does indicate what is possible and what is impossible. Stating it generally, complete vaporization of fuels much less volatile than those now sold is possible without increase of mixture temperatures; condensation of these fuels is impossible. Let us first dispose of the last statement. Manifold condensation is impossible, above the temperature indicated, because it is physically impossible for any vapor to condense when its partial pressure is lower than the determined vapor pressure of the liquid itself at that temperature. This is apparently

TABLE 2—VAPOR TENSIONS IN MM. OF MERCURY AT VARIOUS TEMPERATURES

Temperature, deg. fahr	50	75	100	125	Specific Gravity, Bottoms
Original Gasoline	121.80	180.05	.....	.....	.....
Residuum, per cent					
90	44.75	69.51	115.20	156.35	54.6
80	17.45	31.18	54.92	103.20	52.9
70	16.65	24.65	41.49	69.75	51.3
60	9.66	14.35	24.59	45.82	49.8
50	8.45	13.35	18.41	29.50	48.4
40	4.84	8.08	11.32	17.50	46.2
30	....	6.75	8.48	12.55	45.3
20	....	....	1.64	8.05	43.1
10	....	....	....	5.07	40.1

the average condition in an engine manifold. So far as I know, there is no malicious mechanical magnetism in a gas engine which suspends the operation of the laws of nature. So-called "condensation," in most cases at least, must therefore be the mere separation of liquid which was never vaporized. Precisely there lies the

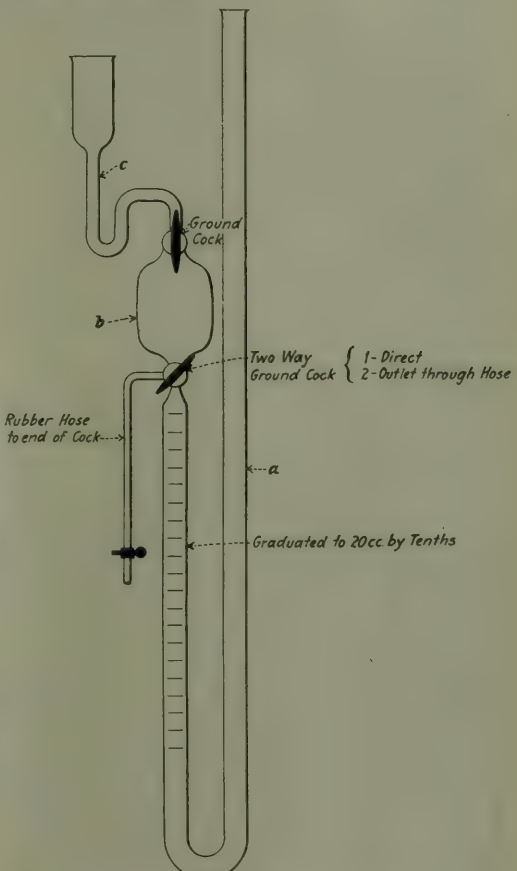


FIG. 1—SPECIAL APPARATUS DEVELOPED TO DETERMINE THE VAPOR TENSION OF GASOLINE

difficulty. Vaporization is possible, and without higher manifold temperatures; but it is difficult to obtain.

REQUIREMENTS FOR FULL UTILIZATION OF INHERENT VOLATILITY

The utilization of the full inherent volatility of the fuel is dependent upon just three things, time, surface and heat. The relation can be expressed mathematically as follows:

$$\text{Vaporization} = \text{Time} \times \text{Surface} \times \text{Heat}.$$

If the time element is large, surface and heat may be infinitely low. If surface is infinitely large, the other two may be infinitely small. If heat is applied rapidly enough and at a high enough potential or temperature, surface and time become unimportant.

So far as I know, no way is promised yet for bettering

the time factor. The other two, however, automotive engineers are bettering daily in several ways. Air heating and manifold heating are helpful, but apparently the means which best meets the physical requirements of volatilization is the so-called hot-spot. The definite problem is to supply heat to the fuel; not to supply heat to the air or to the mixture, but to the fuel itself. This heat should be supplied to the fuel in the presence of the air to have its maximum effect. The latent heat of evaporation of gasoline is about 130 B.t.u. per lb.; its specific heat is about 0.5. Even if we wished to do so, we could not preheat it very much before introduction into the airstream, because such preheating would distill off the lighter fractions and waste them. The latent heat of vaporization must be and should be applied to the fuel as, or after, the mixture is made. One obvious way is to preheat the air; another, to directly heat the charge. However, the heat conductivity of air is so low that, unless these are carried to an extreme which results in substantial loss of power, there is not sufficient time for the necessary exchange of heat between the evaporating fuel droplet or film and the enveloping air current. It can be demonstrated that even in highly heated air a fuel drop of any great size will actually cool off rather than heat up, because the absorption of latent heat in the volatilization of the lighter fractions more than offsets the gain of heat from the air. It can therefore be expected that the temperature of the vaporizing fuel particles themselves, instead of being raised by contact with heated air, may actually be lowered as the evaporation proceeds. From all of the work in our own laboratories on the evaporation of liquids, it seems to me very doubtful whether air heating is of any measurable direct benefit in securing complete evaporation of the fuel. Its indirect benefit is very clear, however, for the heated air heats the walls of the carbureter and intake manifold and, in this indirect fashion, transmits heat to that unvaporized portion of the charge which separates as a film on these walls.

The direct and logical attack on the problem, however, would appear to be to endeavor to throw the unvaporized fuel particles positively out of the insulating airstream, which effectively prevents them from picking up very much heat in their brief travel from the throttle-valve to the engine valves. If the separating surface upon which they impinge were heated to some high temperature, the higher the better, short of the point at which carbon deposits take place, it would be perfectly feasible to take advantage of practically the full inherent volatility of the fuel. It should be noted that a highly heated separating surface upon which the unvaporized fuel particles impinge does not mean a high manifold temperature. The same insulating property of the air which makes vaporization so difficult to obtain in an old-type manifold also makes it possible to heat a separating surface of limited area on the manifold, such as a hot-spot, to a very high temperature without unduly raising the mixture temperature. I hope I have convinced those automotive engineers who may have held a contrary opinion that, so far as the mixture temperature itself is concerned, it is already high enough and that they need not fear condensation, even with fuels much less volatile than those now common.

Apparently the problem which automotive engineers face resolves itself into the further development, improvement and wider use of the hot-spot. I feel that the progress of automotive engineers in this respect has been phenomenal up to the present time. I noticed recently in one of the periodicals an editorial describing a test of a simple form of attachment hot-spot which presumably could be applied to any engine. The test showed that within 36 sec. after the exhaust gases were admitted to the jacket of the hot-spot, the mixture passing the same was perfectly dry as shown by a glass manifold. I once conducted some rather crude tests on a hot-spot of this same design and found that complete vaporization of the fuel was secured in this way with a manifold temperature beyond the hot-spot of 125 deg. fahr. The surface of the hot-spot itself at that time showed a temperature of 350 deg. fahr., as accurately as it could be measured. It is, therefore, apparent that advanced hot-spot design has already reached a point at which automotive engineers can come very close to utilizing the full inherent volatility of the fuel by the simple and logical expedient of directly heating the unvaporized fuel in contact with the air, rather than by trying to preheat the fuel or to heat the fuel by contact with heated air.

It is my hope that some data will have been found in this paper on the physical and chemical properties of internal-combustion engine fuel, from this standpoint of volatility, which will make it easier for automotive engineers to analyze properly the difficulties which they are meeting, and to understand just why and how their most promising mechanical solution of these difficulties operates. This simple solution is not only capable of being incorporated in new designs, but promises to lend itself to attachment to existing engines without great difficulty or expense. Insofar as this proves feasible, we shall apparently be able to perpetuate the mutually advantageous condition of the past, the condition of a single prevailing type of engine in which a single grade of fuel, the cheapest grade, can be used with universal satisfaction.

CORRECT ADDRESSES OF THE MEMBERS

A FORCE is maintained in the offices of the Society at New York City whose sole duty is to keep the addresses of the members uptodate. Approximately 200 changes of addresses are received each week by this department, and these are made promptly. In numerous cases the only notification which the Society has of a change of a member's address is a letter stating that THE JOURNAL, or some other communication, was delayed in delivery or was not received at all. It is of course impossible for the office to have a correct list of addresses unless the members send in such changes promptly. All members who are receiving mail addressed improperly are urged to send their correct address to the office.

A list of the members for which the Society has no correct address is given below. Communications sent to the last known business connection or mail address as it appears on the records have been returned to the New York office. Any one who can supply information regarding the present location of these members or offer any suggestions as to where their correct addresses can be obtained will confer a favor upon the Society by communicating with the Secretary at the New York office. It is only by the cooperation of the entire membership that a correct mailing list can be maintained and the members receive THE JOURNAL and other communications promptly.

BARKER, GEORGE R.
BONNEY, W. L.
GREEN, L. P.
HARDING, HERBERT P.
JOHNSON, A.
LEWIS, WILL I.
MCMILLAN, HORATIO G.
MILLER, JAMES A.
THEISEN, ALEXANDER J.
TUCKER, GORDON E.
WINTER, H. L.

High-Temperature Properties of White-Metal Bearing Alloys

By JOHN R. FREEMAN, JR.,[1] AND R. W. WOODWARD[2]

Illustrated with PHOTOGRAPHS AND DRAWINGS

THE mechanical properties of white-metal bearing alloys have been the subject of several investigations, with the particular object of establishing the relations between the properties obtained in laboratory tests and the ultimate test of service. Practically all of these tests reported in the literature on white-metal bearing alloys were conducted at room temperature, the Brinell hardness[3] alone having been determined for a few alloys under other conditions of temperature. While we therefore have considerable knowledge of the mechanical properties of these alloys at ordinary temperatures, our knowledge of their properties at elevated temperatures is very limited. The importance of knowing the properties of bearing alloys at elevated temperatures is readily appreciated when one considers that the oil temperature in the crankcase of an automobile engine may often reach 60 deg. cent. (140 deg. fahr.) and bearing temperature of 100 deg. cent. (212 deg. fahr.) and higher have been measured in similar engines. It is the purpose of this paper to present the design of new apparatus and the results of tests to determine the mechanical properties in compression and the Brinell hardness of some representative white-metal bearing alloys at elevated temperatures.

The Non-Ferrous Metals Division of the Standards Committee of the Society of Automotive Engineers is proposing as standard white-metal bearing alloys the four compositions given in Table I.

These four alloys and alloy No. 2 of the American Society for Testing Materials[4] were selected as of representative composition suitable for this investigation. The results of a chemical analysis of the five alloys studied are given in Table 2. It will be noticed that alloy No. 2 of the American Society for Testing Materials, given in Table 2, is very similar to alloy No. 11, of the Society of Automotive Engineers, given in Table I. The properties of these two alloys are compared because the former alloy was considered by the committee of the Society of Automotive Engineers as being somewhat too hard.

TABLE 1—SPECIFICATION FOR WHITE-METAL BEARING ALLOYS PROPOSED BY THE SOCIETY OF AUTOMOTIVE ENGINEERS

S. A. E. No.	Per Cent			
	10	11	12	13
Tin	90 to 92	86 to 89	Remainder	4.50 to 5.50
Copper	4 to 5	5 to 6.50	2.25 to 3.75	Less than 0.50
Antimony	4 to 5	6 to 7.50	9.50 to 11.50	9.25 to 10.75
Lead	Less than 0.35	Less than 0.35	24 to 26	84 to 86

PREPARATION OF ALLOYS

Pure Banka tin and the best grade of Star antimony were used. These metals and the copper were not analyzed, as the freedom of the alloys from impurities is proof of the purity of the metals used. An analysis of the commercially pure lead used showed lead, 99.94 per cent; copper, 0.03 per cent and antimony, 0.03 per cent.

Alloys Nos. 1, 2, 3 and 4, were prepared by first melting the tin in a plumbago crucible in a gas furnace. The requisite amounts of a 50 per cent tin, 50 per cent copper hardener and metallic antimony were then added. After the addition of the alloying elements, the temperature of the bath was carried up to the melting point of antimony and stirred to insure a homogeneous alloy. The temperature of melting was then allowed to drop to about 500 deg. cent. (932 deg. Fahr.) with continual stirring of the metal, which was then poured into a cast-iron mold. The surface of the bath was always kept covered with charcoal to prevent excessive oxidation. The temperature was measured by a specially calibrated chromelalumel thermocouple connected to a Leeds and Northrup portable potentiometer. The lead-base alloy No. 5 was similarly prepared but in this case the lead was first melted and then the metallic tin and antimony were added. The al-

[1]Assistant physicist, Bureau of Standards, Washington.
[2]Associate physicist, Bureau of Standards, Washington.
[3]Babbitt and Babbitted Bearings, by Jesse L. Jones, *Transactions, American Institute of Mining and Metallurgical Engineers*, 1919, vol. 60, p. 458.
[4]Tentative Specifications for White-Metal Bearing Alloys Proceedings of the American Society for Testing Materials. Vol. 19, part 1, page 469.

TABLE 2—PERCENTAGE COMPOSITION OF ALLOYS STUDIED[5]

Bearing Metal No.	Society of Automotive Engineers No.	American Society for Testing Materials No.	Per Cent				
			Copper	Antimony	Tin	Lead	Iron
1	10	1	4.56	4.52	Remainder	None	Less than 0.05
2	..	2	3.51	7.57	Remainder	None	
3	11	.	5.65	6.90	Remainder	0.09	
4	12	.	2.90	10.50	Remainder	25.05	
5	13	9	....	10.03	Remainder	84.95	

[5]The authors are indebted to J. A. Scherrer of the Bureau of Standards for all chemical analyses reported.

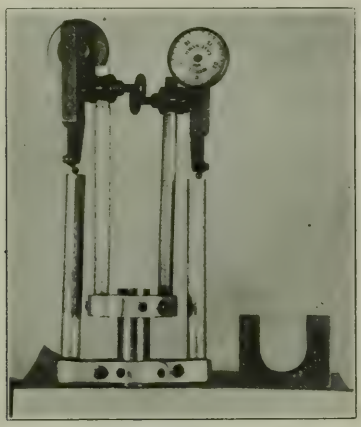


FIG. 1—THE SPECIALLY DESIGNED COMPRESSOMETER USED TO MEASURE THE DEFORMATION OF THE SPECIMENS

loys were made up to meet the mean composition of the specifications and the resultant compositions given indicate how close a desired composition can be obtained with the careful laboratory methods used.

PREPARATION OF TEST SPECIMENS

The compression test-specimens used were small cylinders 1½ in. long and about ½ in. in diameter, this ratio of length to diameter being within the limits recommended by the American Society for Testing Materials and the cross-section for these experiments being suitable for a 10,000-lb. testing machine. These specimens were turned in a lathe, with a hollow mill, from castings 2 in. long and ¾ in. in diameter which were made by pouring the metal from the desired temperature into a split steel mould of the above dimensions.

The samples for Brinell testing were similar to those used by Lynch*, the metal being poured into an open steel mold 2 in. in diameter and ⅝ in. deep, but in this case the mold was not previously heated before pouring, always being at room temperature when the metal was first poured. Before making the impressions, the faces of the casting were turned off and the test was then made on the bottom face. Three impressions were made on each casting at equidistant points on a circle one-half the radial distance from the center. The average of these three readings was taken as the Brinell hardness under the given conditions.

APPARATUS USED FOR TESTING.

For the compression tests, the cylinders were compressed in a standard Riehle 10,000-lb. testing machine. The deformation per unit load was measured by a specially designed compressometer. A copy of a photograph of this instrument mounted on a specimen is shown in Fig. 1. The frame and uprights are made of aluminum. They are held to the specimen respectively by three small steel screws set radially in the same plane and spaced equidistantly around the specimen as shown. The small U-shaped block is a gage used for spacing the frames at the proper distance on the specimen. The distance between the plane of the screws, or the gage length, is 1 in. The Last Word dials used read to thousandths of an inch and ten thousandths can be estimated readily.

The assembly and important dimensions of the bath used for heating the specimen during tests are shown in Fig. 2, which is a section through the center. The specimen *A* is compressed between the steel posts *BB*. During tests the specimen with compressometer attached is immersed in a heated liquid; glycerine was found very satisfactory, held in the container *C*. *D* is a syphon diaphragm. This collapses like an accordion, permitting the top of the container *C* to drop below the level of the base of the specimen. This is a particularly convenient method for lowering the bath to place a specimen in position for testing, especially as it eliminates the need for any packed joints. A photograph of the entire apparatus with a specimen in position for testing is shown in Fig. 3.

The bath is heated with a small-size hot-point electric heater immersed in the glycerine. The glycerine was forced in a continuous stream over the heater by a small motor-driven propeller. This continuous stirring of the glycerine and the ready control of the heating current by a variable resistance provided an excellent control of the temperature of the specimen during the test. In all cases the temperature of the bath and, consequently, that of the specimen, did not vary by more than 2 deg. cent. (3.6 deg. fahr.) during a test.

The Brinell hardness tests were made with a standard

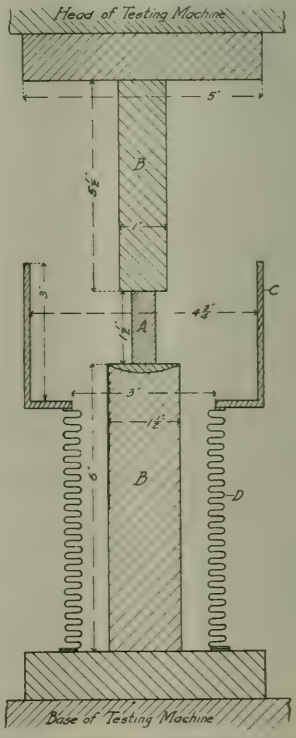


FIG. 2—SECTIONAL ELEVATION OF A PORTION OF THE TESTING MACHINE SHOWING THE ARRANGEMENT OF THE BATH EMPLOYED TO HEAT THE SPECIMEN

*Study of Bearing Metals and Methods of Testing, by T. D. Lynch. *Proceedings of the American Society for Testing Materials*, 1913, vol. 13, p. 699.

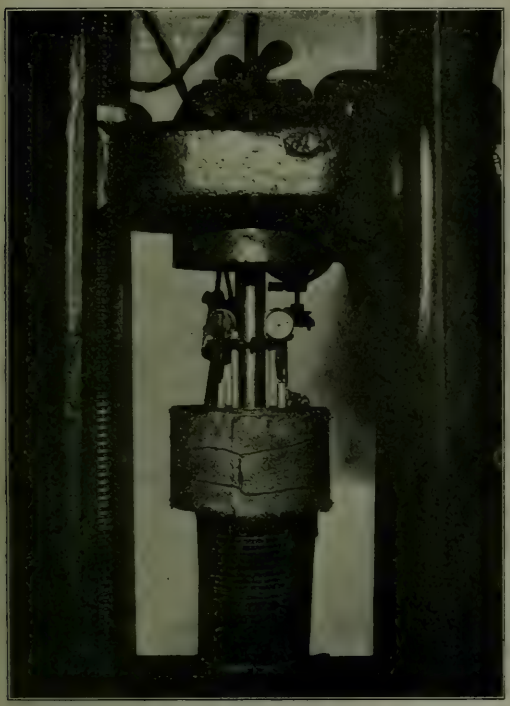


FIG. 3—THE ENTIRE TESTING APPARATUS IN PLACE

Brinell machine using a 500-kg. load on a 10-mm. ball applied for 30 sec. The apparatus shown in Fig. 4 was used for the elevated temperature tests. It is simply a suitable container for the testing liquid, glycerine, with a base made to fit on the spherical seat of the Brinell machine; and a post on the inside to support the specimen away from the bottom and permit good circulation of the liquid around it. The bath was stirred with a small motor-driven propeller and was heated by a small resistor placed in the bottom of the container. During the test the entire specimen was submerged, the Brinell ball also being completely immersed. Sufficient time was always allowed for the specimen to reach the temperature of the bath, this having been determined previously by inserting a thermocouple in a specimen and noting the elapsed time between the placing of the specimen in the bath and when the center reached the temperature of the bath.

PRELIMINARY TESTS

It is well known that the pouring temperature of a bearing metal has a marked influence on the mechanical properties, all other conditions being constant. In view of this fact, preliminary to any test at elevated temperatures the effect of pouring temperature on the compressive strength at room temperature was determined for alloys Nos. 1, 3, 4 and 5. The results obtained are given in Table 3.

In results reported in this paper the yield-point was adopted arbitrarily as being at ⅛ of 1 per cent reduction of the gage length. The ultimate strength was finally

TABLE 3—EFFECT OF POURING TEMPERATURES ON YIELD-POINT AND ULTIMATE STRENGTH

Alloy No.	Pouring Temperature		Yield-Point, lb. per sq. in.	Ultimate Strength, lb. per sq. in.
	deg. cent.	deg. fahr.		
1	400	752	3,750	12,940
	446	835	4,000	12,855
	495	923	3,500	13,500
3	390	734	3,500	15,830
	445	833	4,250	16,435
	500	932	4,000	15,830
4	300	572	5,000	14,015
	350	662	4,250	13,685
	400	752	4,750	13,635
5	300	572	3,250	13,840
	356	673	3,750	15,020
	404	759	3,250	15,245

chosen as the unit load necessary to produce a deformation of 25 per cent of the original length of the test-specimen. The reasons for selecting these values will be discussed later. After comparing the results in Table 3 and the pouring temperatures suggested in the tentative specifications of the American Society for Testing Materials, already mentioned, the temperatures given in Table 5 on page 152 were used in casting test-specimens for all further tests.

ELEVATED-TEMPERATURE COMPRESSION TESTS

Stress deformation curves were taken on all five alloys at room temperature, 20 to 30 deg. cent. (68 to 86 deg. fahr.) and at 50, 75 and 100 deg. cent. (122, 167 and 212 deg. fahr.). At least two specimens were tested

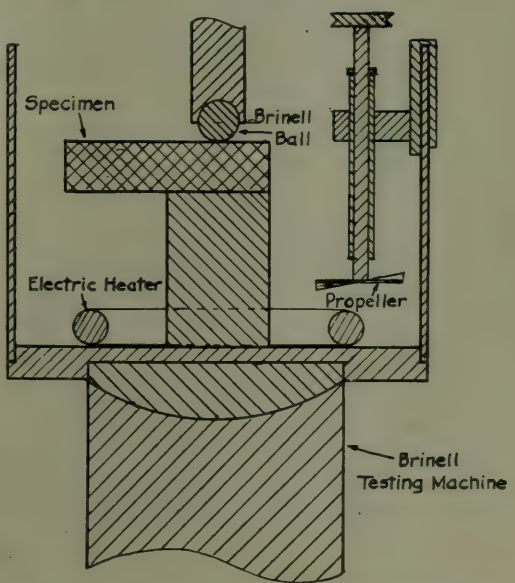


FIG. 4—APPARATUS EMPLOYED IN THE ELEVATED TEMPERATURE TESTS

TABLE 4—TEMPERATURES USED IN CASTING TEST-SPECIMENS

Specimen No.	Pouring Temperature	
	deg. cent.	deg. fahr.
1	440	824
2	440	824
3	440	824
4	345	653
5	325	617

under each condition to provide a check. Representative stress-strain curves of each alloy except No. 2, at the four temperatures, are given in Fig. 5. These show the type of stress deformation curve obtained with the apparatus described, and also show very clearly the marked change in the compressive strength of the alloys with increasing temperatures. In Fig. 5 a dial unit is equivalent to 0.00087 in. and is the algebraic mean of the total deformation shown by the individual dials for any given load.

A study of the curves shows that it is practically impossible to pick out a limit of proportionality as ordinarily determined by noting the departure of the stress deformation curve from a straight line and, further, we know that the finer the measurement is, the lower this point will be. An arbitrary yield-point was therefore determined upon. After comparing the yield-points indicated by several values of percentage reduction of gage length, the value of ⅛ of 1 per cent of the gage length, or 0.00125 in., was adopted for purposes of comparison as it generally seems to coincide with the first marked yielding of the specimens tested. This value, 0.00125 in., is practically equivalent to 1.5 division on the dial or "dial units" used in Fig. 5.

When soft metals of this type and size of test-specimen are compressed they do not eventually shear but continue to flatten out with increasing loads, so it is necessary to adopt some arbitrary values for ultimate strength which will at least be comparable among themselves. A reduction of 25 per cent of length was chosen in this investigation as at this value in all cases the load had become nearly constant for increasing deformation. In the case of high-lead alloys, the load generally reached a maximum value and then fell off before the 25-per cent reduction was reached. In these cases the maximum load was recorded. The values of yield-point and ultimate strength thus obtained are given in Table 5.

ELEVATED TEMPERATURE BRINELL TESTS

The Brinell hardness of alloys Nos. 1, 3, 4 and 5 was determined at room temperature, 50, 75 and 100 deg. cent. (77, 122, 167 and 212 deg. fahr.). The values obtained are given in Table 6.

DISCUSSION OF RESULTS

Regarding the *compression tests*, the yield-points of the four alloys are plotted against temperature in Fig. 6, for greater convenience of comparison. As one would expect from the composition, the yield-point of alloy No. 3 is considerably higher at all temperatures than that of the other alloys. The yield-point of alloy No. 3, however, falls off more rapidly, with increasing temperatures than does the yield-point of alloy No. 1. The points in both these cases appear to lie on a straight line. This is not the case with alloys Nos. 4 and 5, which contain lead. The yield-point of each of alloys Nos. 4 and 5 seems to drop off more rapidly at first, between 25 and 50 deg. cent. (77 and 122 deg. fahr.). It is significant to note that while the yield-point of alloy No. 4 is higher than that of alloy No. 1 at room temperature, it is lower at 50 deg. cent. (122 deg. fahr.) and decreases at a more rapid rate between 25 and 100 deg. cent. (77 and 212

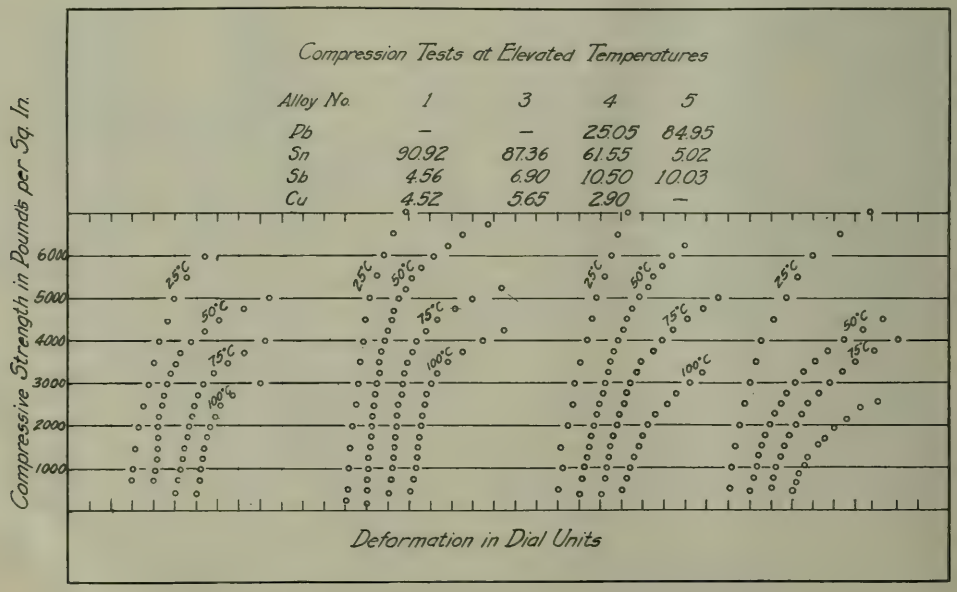


FIG. 5—STRESS-STRAIN CURVES OF THE ALLOYS AT DIFFERENT TEMPERATURES

TABLE 5—YIELD-POINT AND ULTIMATE STRENGTH VALUES

Temperature		Yield-Point, lb. per sq. in.					Ultimate Strength, lb. per sq. in.				
deg. cent.	deg. fahr.	Alloy No.					Alloy No.				
		1	2	3	4	5	1	2	3	4	5
25	77	4,400	6,250	5,750	4,700	3,750	12,850	15,175	16,425	13,685	15,020
50	122	3,800	4,850	5,000	3,650	2,650	10,400	11,850	12,175	10,035	11,275
75	167	3,150	4,000	4,250	2,900	2,250	8,450	9,400	10,100	7,845	7,920
100	212	2,650	2,850	3,350	2,150	1,550	6,950	6,825	7,725	6,045	4,771

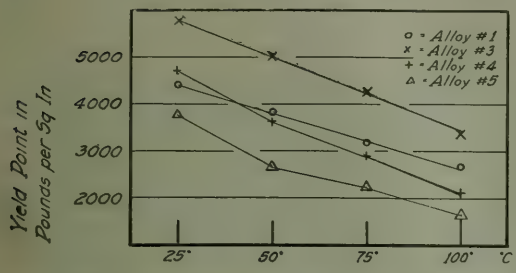


FIG. 6—RELATION BETWEEN THE YIELD-POINTS AND THE TEMPERATURE

deg. fahr.) than does that of alloy No. 1, and that the yield-point of tin-base alloys is higher at all temperatures above 50 deg. cent. (122 deg. fahr.).

The yield-point of alloy No. 2, curves of which are not given, is slightly higher at room temperature than that of alloy No. 3, but at 50 deg. cent. (122 deg. fahr.) its yield-point is slightly less than that of alloy No. 3; so, any advantage gained by using alloy No. 2 in a bearing is lost if the bearing heats to 50 deg. cent. (122 deg. fahr.), or over, insofar as the yield-point is concerned.

In Fig. 7, curves are given showing the variation of the ultimate strength with the temperature. Here, as with the yield-point, alloy No. 3 has the maximum value throughout the temperature range and alloys Nos. 1 and 3 maintain their strength better, having a higher ultimate strength at a temperature above 60 deg. cent. (140 deg. fahr.) than either alloy No. 4 or alloy No. 5, which contain lead, even though the ultimate strength of alloy No. 1 is less than that of either alloy No. 4 or alloy No. 5, at room temperature. The ultimate strengths of the four alloys at 100 deg. cent. (212 deg. fahr.) stand in the same relation to each other as their respective yield-points.

Concerning the Brinell hardness tests, it is noted that the Brinell hardness values obtained for the tin-base alloys are considerably lower than those usually given. This difference may be due to the small percentage of impurities in the alloys used in this investigation, as compared with similar alloys as ordinarily prepared. Curves showing the variations of the Brinell hardness with temperature are given in Fig. 8 on page 154. Here again, alloy No. 3 has a maximum value throughout the temperature range. There is no evident relation between the relative magnitude of either the ultimate strength or yield-point and the Brinell hardness.

The hardness of alloys Nos. 4 and 5, however, drops off very rapidly with increasing temperature, while alloys Nos. 1 and 3 maintain their hardness, each having a greater hardness at 100 deg. cent. (212 deg. fahr.) than alloy No. 4, and alloy No. 1 having the same hardness value as that of alloy No. 5 at this temperature.

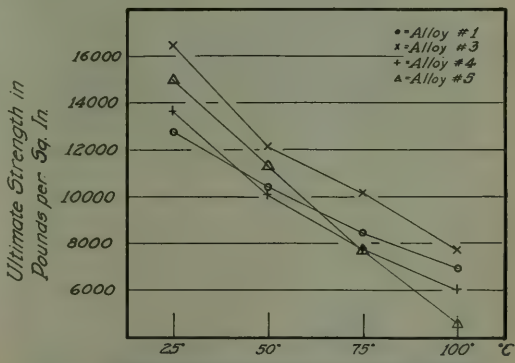


FIG. 7—CURVES SHOWING THE VARIATION OF THE ULTIMATE STRENGTH WITH THE TEMPERATURE

TABLE 6—BRINELL HARDNESS OF ALLOYS AT DIFFERENT TEMPERATURES

Temperature		Brinell Hardness[7]				
deg. cent.	deg. fahr.	Alloy No.				
		1	2	3	4	5
25	77	17.2 (28.6)	22.3 (28.3)	22.3	22.4	19.7 (19.5)
50	122	13.8	.....	18.2	15.8	16.8
75	167	11.1	.....	14.8	11.3	11.4
100	212	8.2 (12.8)	.....	11.3	7.5	8.2 (8.6)

[7]The values shown in parentheses are taken from the specifications of the American Society for Testing Materials.

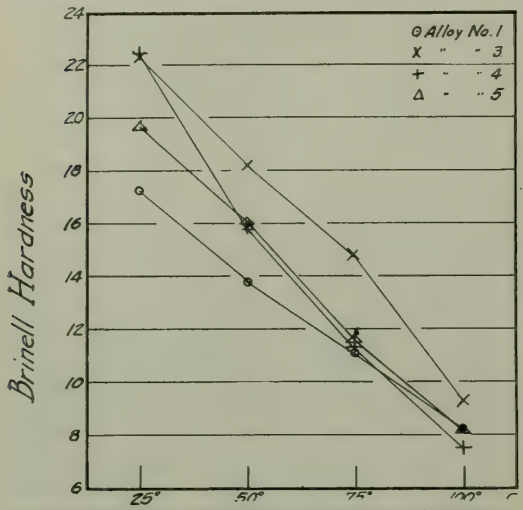


FIG. 8—VARIATION IN THE BRINELL HARDNESS WITH CHANGES IN TEMPERATURE

EFFECT OF LONG-PERIOD HEATING

A babbitted bearing which has given good service often will gradually become soft and "wipe out" for no apparent reason. As a working hypothesis it was thought that this failure with age might be due to softening from prolonged heating, causing an annealing action. To determine the validity of this tentative hypothesis, compression specimens of alloys Nos. 1, 3, 4 and 5, were heated in an oil-bath for from one to six weeks at temperatures between 90 and 100 deg. cent. (194 and 212 deg. fahr.). They were then tested at room temperature with the results given in Table 7.

A study of Table 7 indicates, for alloys Nos. 1, 3 and 4, that heating at 100 deg. cent. (212 deg. fahr.) for 42 days has no appreciable effect on the value of the yield-point when the specimens are cast in the manner indicated. For alloy No. 5, however, there is a very evident decrease in the value of its yield-point with the prolonged heating which, however, evidently takes place within the first two weeks of the heating.

EFFECT OF SMALL PERCENTAGES OF LEAD

The specifications for high-grade tin-base alloys such as Nos. 1, 2 and 3, call for a low lead content, generally not to exceed 0.35 per cent. Many believe and Jesse L. Jones has presented experimental evidence in his book on Babbitt and Babbitted Bearings, previously cited, that percentages of lead even up to 5 per cent are not harmful but possibly beneficial. We have therefore investigated the effect of small percentages of lead on the yield-point and ultimate strength of alloy No. 2 at room temperature and at 75 deg. cent. (167 deg. fahr.). The alloys were prepared by adding metallic lead to the No. 2 babbitt, in amounts shown by the chemical analysis given, together with the yield-points, in Table 8.

The addition of up to 5 per cent of lead to this babbitt seems to have no very appreciable effect on its mechanical properties in compression, at room temperature or at 75 deg. cent. (167 deg. fahr.), under the conditions of test used. We think, however, that this should not too greatly influence toward the raising of the lead tolerance in the tin-base bearing-metal specifications until much more work is done along this line, particularly to determine the possible effect of small percentages of lead on the resistance to repeated impact.

TABLE 7—EFFECT OF PROLONGED HEATING AT 100 DEG. CENT. (212 DEG. FAHR.) ON THE YIELD-POINT

Heating Period, days	Yield-Point, lb. per sq. in. Alloy No. 1	2	3	4	5
0	4,550	....	5,750	4,650	3,750
7	4,500	....	5,500	....	3,450
14	4,600	....	5,800	4,250	3,200
28	5,025	....	5,650	4,750	2,800
42	4,900	....	5,950	4,850	3,150

[8]One specimen only; all other values are the average of two specimens.

SUMMARY AND CONCLUSIONS

An apparatus is described for determining the yield-point and ultimate strength of white-metal bearing alloys at temperatures up to 100 deg. cent. (212 deg. fahr.). A new design of heating apparatus is described for determining the Brinell hardness of metals at temperatures up to 100 deg. cent. (212 deg. fahr.).

The results of compression tests and Brinell hardness

(*Concluded on page* 162)

TABLE 8—EFFECT OF SMALL PERCENTAGES OF LEAD ON THE YIELD-POINT AND ULTIMATE STRENGTH

Metallic Lead Added, per cent	Yield-Point, lb. per sq. in. Temperature 25 deg. cent. (77 deg. fahr.)	75 deg. cent. (167 deg. fahr.)	Ultimate Strength, lb. per sq. in. Temperature 25 deg. cent. (77 deg. fahr.)	75 deg. cent. (167 deg. fahr.)
0.00	6,150	4,000	15,175	9,397
0.26	5,850	3,700	15,640	10,010
0.51	5,750	3,300	14,025	9,763
1.01	6,300	.....	.....	.....
1.25	6,000	4,100	16,380	10,600
5.04	5,850	3,850	15,330	9,725

The Application of Steam Power to an Automotive Truck

By Lewis L. Scott[1]

Chicago Truck and Tractor Meeting Paper *Illustrated with* Photographs and Drawings

In connection with possible changes of detail in the design of automotive trucks, that have been brought to view by increased speed and the use of pneumatic tires, and because of the present status of the fuel situation, it occurred to me that a truck having an engine steam engine is located crosswise on the truck frame, as shown in Figs. 1 and 2, about where the transmission usually is on a truck driven by an internal-combustion engine. No transmission or clutch is used. In our latest design the engine is located just at the rear of the

Fig. 1—View of the Complete Truck Showing Crosswise Position of the Engine on the Truck Frame

driving a rear-axle worm direct through a drive-shaft equipped with a 5 to 1 gear reduction at the axle and that could be operated without any transmission or clutch, would be interesting to truck designers. A description of the steam-operated 2-ton truck developed by E. C. Newcomb and me, which offers a solution to these problems, should consequently be of general interest.

In my previous paper, Steam Automotive System,[2] the details of design of the steam engine used on this 2-ton truck were described, but the engine has been simplified since that time. The changes in the construction of the engine relate to valve gear, crankshaft and cam design, and include many details that would not be of particular interest at present because of a lack of general knowledge of the problems involved. However, as very little is known concerning an engine that uses high pressures and temperatures for this kind of service, the details of its development can best be discussed thoroughly in a separate paper and I hope to do this later.

This truck was designed to carry a 2-ton load. The

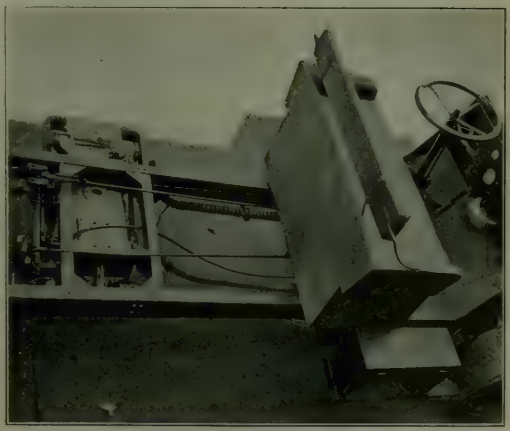


Fig. 2—View Looking Down on the Truck Showing Relation of Engine Location to the Driver's Seat

[1] M.S.A.E.—Chief engineer, Standard Engineering Co., St. Louis.

[2] Printed in the November, 1919, issue of The Journal, p. 353.

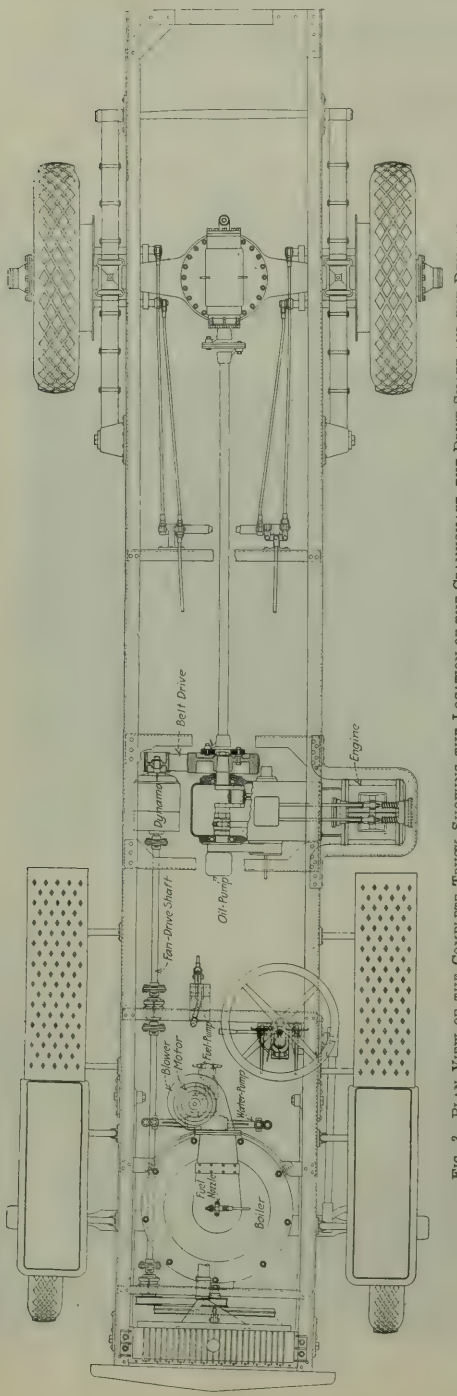


FIG. 3—PLAN VIEW OF THE COMPLETE TRUCK SHOWING THE LOCATION OF THE CRANKSHAFT, THE DRIVE-SHAFT AND THE DYNAMO

driver's seat and can be mounted either horizontally or vertically as desired. By so locating the engine the steam and the exhaust lines are shortened and so is the shaft that drives the radiator fan, but the axle drive-shaft is thus made longer. The engine shaft is directly connected to the worm-driven axle through a drive-shaft. The camshaft, which operates the valves, is adapted to be shifted axially for controlling the cut-off and reversing the engine when backing the truck. A pedal operated by the left foot, similar to the clutch pedal on a truck driven by an internal-combustion engine, is used to shift the cam.

A sectional drawing of the engine, showing the crankshaft, drive-shaft and dynamo drive is reproduced in Fig. 3, and the relative positions of the various parts of the system are brought out in Fig. 4. It is surprising how free this engine is from vibration and how smoothly it operates, even without a flywheel. The engine has two double-acting cylinders of 4-in. bore and 5-in. stroke and gives the same number of impulses as does an eight-cylinder internal-combustion engine, with the added flexibility of steam. It will be noted that a one-piece crankshaft is used, with plain connecting-rod bearings, and two ball bearings for the journals. The engine flywheel serves as a pulley to drive the dynamo and affords an arm to which to attach the thermoid coupling. The front end of the dynamo shaft serves as a drive for the radiator fan.

ADVANTAGEOUS FEATURES

The features of special interest in this steam power-plant are that

(1) Because the engine is directly connected to the drive-shaft, it cannot be run unless the rear wheels also turn. This prevents racing the engine or allowing it to run when loading or unloading the truck, which is a common practice with some drivers
(2) All kinds of road can be negotiated with the same gear-ratio between the engine and the rear axle
(3) The dump type of body can be used satisfactorily because a steam hoist can be installed if desired
(4) Driving is more simple and the number of accidents should be reduced for this reason
(5) The rapid acceleration is conducive to safer operation at street corners and intersections
(6) No gear-shifting is necessary when starting
(7) Carbon does not collect in the engine
(8) The valves do not require re-grinding
(9) Dust cannot be sucked into the engine and the truck should, on this account, remain operative for longer continuous periods than in the case of trucks driven by an internal-combustion engine

The boiler is located under the hood as shown in Fig. 5. Steam can be raised in less than 1 min. from a cold start. No effort is required in getting up steam other than turning a switch. No stuffing-boxes are used on the engine or pump. The water and fuel-pumps are operated by an electric motor, which is controlled by a switch on the steam gage.

Fuel oil, gas oil, kerosene, gasoline or any mixture of these fuels can be used. This makes possible the utilization of 80 per cent of the crude oil available. It is possible also to use powdered coal or coke as a fuel. The fuel is cleanly and completely burned, without experiencing any of the long list of troubles common to the explosive type of engine that are due to the present grade of gasoline.

The lubricating oil, which can be of the same grade as that used to lubricate internal-combustion engines, is

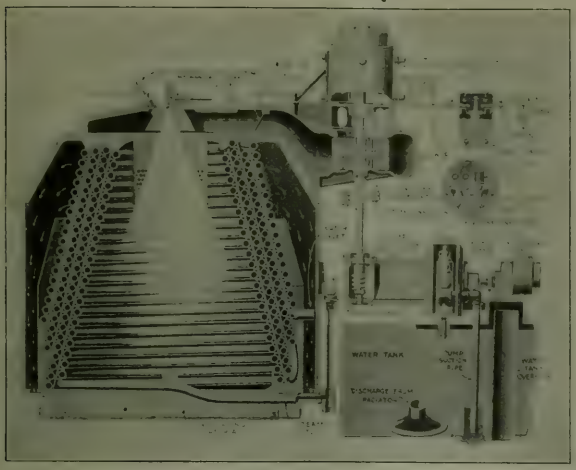


FIG. 4—THE RELATIVE POSITION OF THE DIFFERENT PARTS OF THE SYSTEM

carried in the crankcase of the engine. All parts in the crankcase are lubricated by splash. A small valveless oil-pump is used to pump oil from the crankcase to the steam line for lubricating the cylinders. The engine is of the poppet-valve type, and the valves require little or no oil.

The weight of this steam powerplant, including the engine, boiler and water, is practically the same as that of an internal-combustion engine powerplant of similar capacity, inclusive of the cooling system, clutch and transmission.

TORQUE CURVES

Fig. 6 on page 158 shows the characteristic torque curves of the internal-combustion engine and the steam engine powerplants, the two becoming identical at 1000 r.p.m. The particularly noteworthy feature is the ability of the steam engine to maintain a constant horsepower over almost the entire range of speed on the short cut-off, thus insuring maximum economy of operation above 300 r.p.m.

Fig. 7 on page 158 shows the respective performances of these powerplants when applied to a 2-ton truck having a gross weight, when loaded, of 11,000 lb. Each is a high-speed truck equipped with 8 x 40-in. pneumatic tires on the rear wheels and has a 5 3/7 to 1 gear-ratio in the axle. The low and the intermediate gear-ratios between the engine and the rear wheels are assumed to be 50 to 1 and 25 to 1 respectively. For purposes of illustration, only three speeds are assumed. This is not in accordance with usual practice for this particular case, but it introduces sufficient gear changes to demonstrate the method of operation. The efficiency of the worm-gear axle is assumed to be 90 per cent in each case and the transmission also is assumed to be 90 per cent efficient.

It is noteworthy that the steam-engine curve in Fig. 7 on page 158 meets the tractive effort of the truck equipped with the internal-combustion engine at 22 m.p.h. and that the steam-engine performance is above that of the internal-combustion engine at all other points. When grades become steep, gear-shifting must be resorted to in using an internal-combustion engine powerplant. With a truck so driven, when starting a load up a heavy grade it is very difficult to change to a higher gear without stalling the engine and many drivers will continue to use low gear, racing the engine to acquire speed. The truck driven by a steam engine does not encounter this difficulty. Fig. 8 on page 158 shows the performance on grades of each of the powerplants shown in Fig. 7 on that page.

ENGINE CONTROL

In regard to engine control, the truck is started forward simply by opening the throttle. For an extreme pull, the cam is shifted into the long cut-off position by pushing the left pedal forward until it comes to a stop. As no latch is provided in the long cut-off, the driver naturally will release the left pedal, which will shift the cam to the short cut-off. In the short cut-off position any kind of running can be accomplished, even the climbing of a 14-per cent grade at 8 m.p.h. When extreme grades are encountered, the cut-off can be lengthened by pressing the left pedal forward.

To reverse the engine for backing the truck, the left pedal is moved forward until it strikes the long cut-off stop; then, by tilting the pedals slightly, it will clear the long cut-off stop and can be pushed forward until it stops. This is the reverse position. It is possible to use the reverse as an emergency brake, thus eliminating the necessity of equipping the truck with air brakes.

All parts of the powerplant are accessible. The boiler top can be removed and the coils exposed within a few minutes. The spark-plug and the fuel-spray nozzle are located at the top of the boiler and can be removed quickly. Access to the fuel and water-pumps is afforded by the ample space allowed under the foot-boards. The gages are mounted on the dash and when the hood is raised their connections are exposed. The two connecting-rod bearings are the only ones in the engine that are adjustable and they can be reached easily by removing the back cover of the engine case. The engine can be removed from the truck within 10 min. It should be borne in mind that this type of engine requires no valve-grinding or carbon-deposit removal, and that it has no carbureter, magneto, spark-plugs and the like.

In view of the fact that this truck has no transmission, in the accepted sense of this term, there is a material

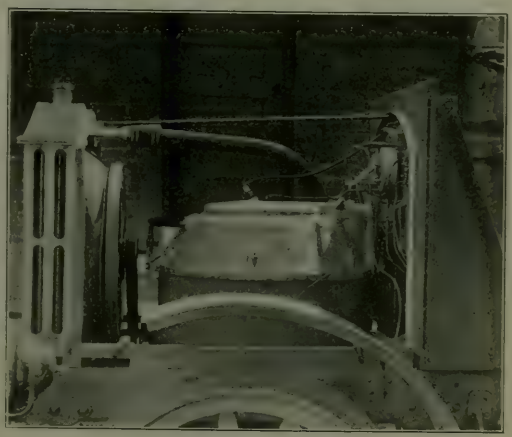


FIG. 5—THE BOILER IS LOCATED UNDER THE HOOD

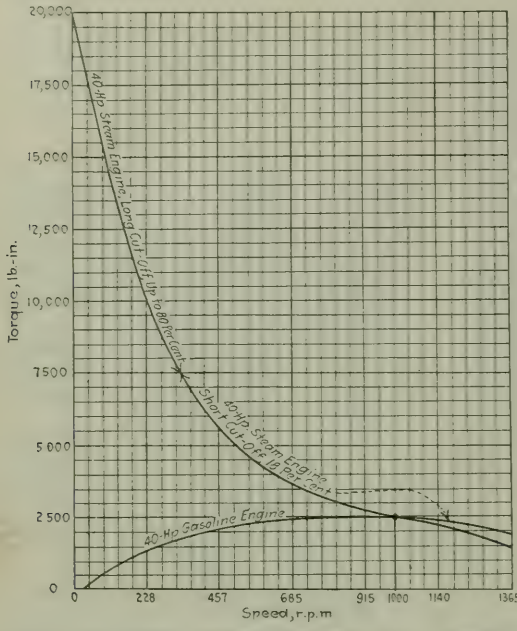

Torque, lb.-in.
Speed, r.p.m
40-Hp Steam Engine, Long Cut-Off Up to 80 Per Cent
40-Hp Steam Engine Short Cut-Off 18 Per Cent
40-Hp Gasoline Engine

FIG. 6—CHARACTERISTIC TORQUE CURVES OF A 40-HP. INTERNAL-COMBUSTION ENGINE AND A STEAM ENGINE DEVELOPING THE SAME POWER

saving in power. This type of steam engine shows about the same efficiency at one-quarter load as at full load, which is must better performance than that of the internal-combustion engine. I understand that gearbox efficiency becomes as low as 70 per cent in some instances.

With a gear-reduction at the rear axle of from 5 to 5½ to 1, it is possible to slip the rear wheels on a dry pavement when the truck is fully loaded. When the truck is traveling 25 m.p.h., the engine speed is about 1200 r.p.m.

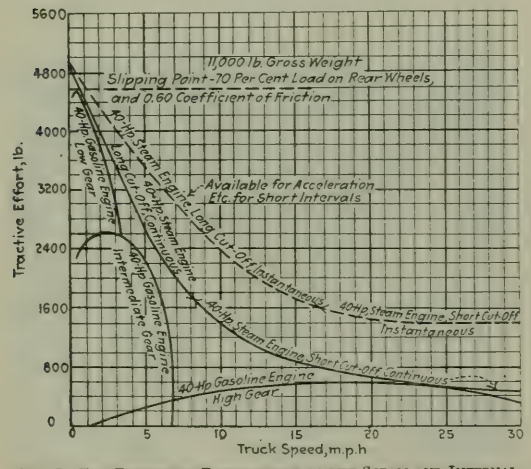

Tractive Effort, lb.
Truck Speed, m.p.h
11,000 lb. Gross Weight
Slipping Point-70 Per Cent Load on Rear Wheels, and 0.60 Coefficient of Friction
40-Hp Gasoline Engine Low Gear
40-Hp Steam Engine Long Cut-Off Continuous
Available for Acceleration Etc. for Short Intervals
40-Hp Gasoline Engine Intermediate Gear
40-Hp Steam Engine Long Cut-Off Instantaneous
40-Hp Steam Engine Short Cut-Off Instantaneous
40-Hp Steam Engine Short Cut-Off Continuous
40-Hp Gasoline Engine High Gear

FIG. 7—THE RESPECTIVE PERFORMANCE OF THE STEAM AND INTERNAL-COMBUSTION ENGINES WHEN APPLIED TO A 2-TON TRUCK HAVING A GROSS WEIGHT OF 11,000 LB.

The high torque at low engine speeds makes the gearbox unnecessary and allows this plant to fit into the high-speed pneumatic-tired truck without excessive engine speed and without transmission or clutch.

As an example of the advantage of eliminating the transmission and clutch on trucks used in bus service in some of the large cities as many as 1000 stops per day are made, requiring several thousand gear-changes. Frequent stops and starts with a heavy load are very destructive to a truck equipped with an internal-combustion engine, with which a transmission and a clutch are required. There has been considerable comment on the adaptability of the internal-combustion engine driven truck to bus service. The steam plant is ideal for this service, some of its advantages being smooth operation, rapid acceleration, flexibility, self-starting with no chance of "killing" the engine at some critical moment, that when the bus stops the engine also stops, and that exhaust steam heat for cold weather is available at no extra expense.

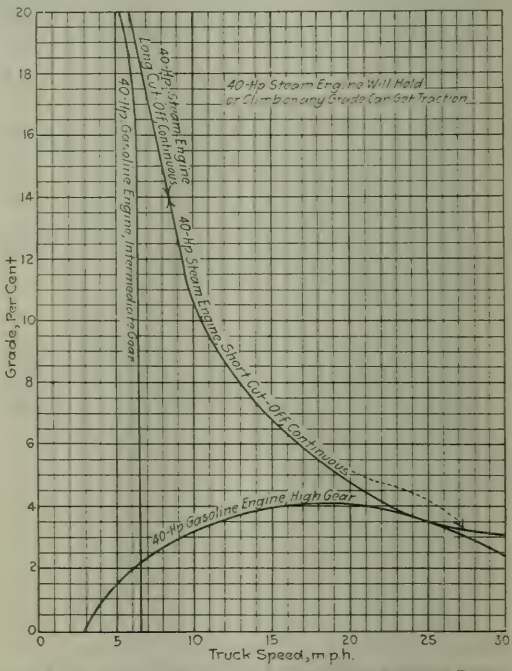

Grade, Per Cent
Truck Speed, m.p.h.
40-Hp Steam Engine Will Hold or Climb any Grade for Good Traction
40-Hp Gasoline Engine, Intermediate Gear
40-Hp Steam Engine Long Cut-Off Continuous
40-Hp Steam Engine Short Cut-Off Continuous
40-Hp Gasoline Engine, High Gear

FIG. 8—COMPARATIVE PERFORMANCE OF THE TWO TYPES OF POWER-PLANT ON GRADES

At atmospheric temperatures of 85 to 90 deg. fahr., we have driven a fully loaded truck 700 miles on the streets of St. Louis with only one tank of water. In cool weather, this water mileage is increased greatly. Long water mileage is important because it reduces the foreign matter brought into the system and no trouble is caused by encrustation of the boiler tubes; also, it permits the use of alcohol to prevent freezing in cold weather.

FUEL, OIL AND WATER CONSUMPTION

With a load of 4400 lb. we get from 5½ to 6 miles per gal. of fuel, with either kerosene or fuel oil, and 300 miles per gal. of lubricating oil, with solid tires. A communi-

TABLE 1—ACCELERATION TESTS—CHASSIS ONLY—NO LOAD[3]

From Zero Speed to M.p.h.	SOUTH Time, Sec.					Average Time, Sec.	Acceleration, M.p.h. per Sec.	NORTH Time, Sec.					Average Time, Sec.	Acceleration, M.p.h. per Sec.
	1	2	3	4	5			1	2	3	4	5		
10	3.6	..	3.0	2.7	3.0	3.08	3.25	3.0	3.0	3.0	2.6	2.7	2.87	3.49
15	5.4	..	4.0	4.7	4.4	4.62	3.25	4.0	4.8	4.4	4.4	4.4	4.40	3.41
20	7.2	7.2	6.8	6.2	6.7	6.82	2.93	5.8	7.8	6.9	7.4	6.4	6.86	2.92

[3]Using long cut-off for starting; then using short cut-off. Run was made on level ground.

cation from one of the large oil companies dated Sept. 30, 1920, quoted water-white kerosene of 41-deg. specific gravity, in tank-car lots, at 11 cents per gal. f.o.b. Tulsa, Okla. Gasoline was quoted in similar quantities at 23 cents per gal. f.o.b. Tulsa, and 24-deg. specific gravity fuel oil in tank-car lots was priced at 8¼ cents per gal., f.o.b. Sand Springs, Okla. It should be remembered that the radiator is entirely empty when the truck is not running. When the truck is running the radiator is used to condense the steam into water, which then runs into the water-tank. The parts containing water are located around the boiler, which will retain heat for 12 hr.

In localities where the water contains large quantities of calcium and magnesium, it can be run through a small tank containing a mineral substance resembling clay or shale that is mined in South Dakota and makes the water softer than rain water. A tank of the size used in residences for heating water will soften 1000 gal. per day. This material is highly charged with exchangeable sodium. It is placed in a filter container in this condition and the water to be softened is passed through it. Having a strong affinity for the calcium and the magnesium in the water, the substance combines with these elements and gives up its sodium to the water in proportionate amounts. When the substance has become charged with calcium or magnesium, by a simple process of admitting a solution of sodium chloride the mineral substance is restored to its original state.

The saving in fuel and oil costs in comparison with the internal-combustion engine driven truck is evident, to say nothing of the saving in unkeep and repair due to the freedom from valve-grinding and carbon removal and to the elimination of the transmission and clutch.

On a 2-ton truck operating 60 miles per day, I estimate that a saving in fuel cost of $1 per day can be effected with the steam powerplant, thus saving $300 per year. The saving on lubricating oil at 25 cents per day would amount to $75 per year. Adding the saving because of the elimination of valve-grinding and carbon removal, about $30 per year, and the saving on general overhauling, about $100 per year, brings the total estimated saving to $505 per year.

ACCELERATION TESTS

It is well known and generally recognized that any properly made steam car can accelerate much more quickly than can one driven by an internal-combustion engine. Attention is called again to the long cut-off

TABLE 2—ACCELERATION TESTS—CHASSIS ONLY—NO LOAD[4]

From Zero Speed to M.p.h.	Time, Sec.		Average Time, Sec.	Acceleration, M.p.h. per Sec.
	1	2		
10	....	3.0	3.0	3.33
15	....	4.5	4.5	3.33
20	7.0	7.2	7.1	2.82

[4]Using long cut-off throughout.

curve in Fig. 7. Acceleration tests of this truck were made at St. Louis by representatives of the Fifth Avenue Coach Co., of New York City, in November, 1920. Table 1 gives the results obtained in runs made with the chassis only, with no load, on a level street. The nominal diameter of the rear tires was 40 in. and their actual diameter 43 in. The speedometer was checked by counting the number of wheel revolutions per mile, this number being 938. The weights are as follows: Chassis, 5960 lb.; allowed for three passengers, 505 lb.; total weight, 6465 lb. The weight on the front wheels was 3100 lb. and that on the rear wheels 2860 lb. Under the same conditions as stated for the tests in Table 1, but using the long cut-off throughout, the results given in Table 2 were obtained.

In runs made after the body and the load had been

TABLE 3—ACCELERATION TESTS UNDER LOADED CONDITIONS—TOTAL WEIGHT, 11,065 LB.

From Zero Speed to M.p.h.	SOUTH Time, Sec.					Average Time, Sec.	Acceleration, M.p.h. per Sec.	NORTH Time, Sec.					Average Time, Sec.	Acceleration, M.p.h. per Sec.
	1	2	3	4	5			1	2	3	4	5		
10	5.0	4.0	4.2	..	3.2	4.10	2.44	3.4	4.2	3.2	3.8	3.2	3.51	2.85
15	9.0	6.4	7.2	7.0	6.0	7.12	2.11	6.0	6.5	5.8	5.9	6.0	6.04	2.30
20	12.0	11.0	11.7	10.3	11.1	11.22	1.78	10.0	10.0	9.5	8.9	8.8	9.44	1.95

placed on the chassis, the weight complete was 10,560 lb.; allowed for three passengers, 505 lb.; total weight, 11,065 lb. The weight on the front wheels was 3795 lb. and that on the rear wheels 6765 lb., without passengers. The acceleration test results are given in Table 3 on page 5.

Alternate readings were taken of the blower periods, on and off, in runs made with the chassis loaded. The first run covered a distance of 4.95 miles with no stops. The blower was on 33.8 per cent, and off 66.2 per cent of the time. Under similar conditions, except that sixteen 5-sec. stops were made and that the distance was 5 miles, within the elapsed time of 19 min. and 19 sec., the blower was on 30.5 per cent, and off 69.5 per cent of the time. Table 4 gives the results of braking tests made on level ground.

TABLE 4—STEAM BRAKE TESTS

Run No.	Time, sec.	Distance, ft.	Speed, m.p.h.	Direction
Reverse, with no steam				
1	8 4	54	15	South
2	8 0	60	14	South
3	10 0	63	16	North
4	9 0	72	14	North
5	10 0	81	15	North
Reverse, with steam				
1	7 4	51	15	North

Acceleration tests were made also on the grade locally known as Dead Man's Hill, the loaded weight being 11,065 lb. The run to the bottom of the hill is 7.75 miles, which was made in 24.84 min. at an average speed of 19.2 m.p.h. The speed at the bottom of the hill was 28 m.p.h. and the lowest speed on the hill, which has a 10-per cent grade and is a winding road, was 15 m.p.h. The results of these tests are given in Table 5.

TABLE 5—ACCELERATION TESTS ON DEAD MAN'S HILL—TOTAL WEIGHT, 11,065 LB., GRADE 10 PER CENT.—WINDING ROAD

From Zero Speed to M.p.h.	Time, Sec.			Average Time, Sec.	Acceleration, M.p.h. per Sec.
	1	2	3		
5	....	3.2	3.7	3.4	1.470
10	8.0	4.8	4.8	4.8	2.080
15	27.0	22.6	21.8	22.2	0.675

A test was made on the failure of the spark to light the fuel spray. The spark-plug wire was disconnected from the spark-plug and the fuel was then turned on, thereby filling the combustion-chamber with kerosene vapor. When the fire was lighted again in the normal way, there was no explosion nor any smoke.

Another test was made on the failure of the fuel system. The fuel was prevented from entering the combustion-chamber, thereby allowing the boiler to fill with water after the temperature was sufficiently low. After a short period the engine was cut off by the pressure gage. No damage whatever occurred.

A third test was made on the failure of the water system. The water was by-passed, thereby allowing the temperature to climb. The temperature reached 780 deg. fahr. and then the fuel was shut off by the solenoid valve.

Additional tests were made on Nov. 14, 15 and 16, 1920, the total loaded weight being 11,065 lb. in each case, with results as stated under Runs Nos. 1, 2, 3 and 4, following:

ADDITIONAL RUN NO. 1

Total distance, miles	49.9
Elapsed time, hr.	3¼
Starting time from cold boiler, min.	1
Temperature at 0.2 miles distance, deg. fahr.	650
Miles run on stored steam	0.4
Number of stops made	178
Average speed, m.p.h.	15.3
Water used, gal.	1
Fuel used, gal.	9⅛
Miles per gallon of fuel	5.49

Note:—After 3 hr. 3 min. the brush on the dynamo became loose.

ADDITIONAL RUN NO. 2

Total distance, miles	35.5
Elapsed time, hr.	1¾
Average speed, m.p.h.	20.3
Maximum speed, m.p.h.	32.0
Minimum speed, Solomon Hill, m.p.h.	13.0
Fire cut off on 10-per cent Solomon Hill grade	3 times
Miles per gallon of fuel	6.59
Water used, gal.	Slightly less than 2

ADDITIONAL RUN NO. 3

Total distance, miles	6.2
Fuel used, gal.	1

Note:—Appeared to run the same as with kerosene, with no odor or smoke.

Additional Run No. 3, made on fuel oil by Messrs. Wotton and Reese, was only for the purpose of testing the operation of the truck. It was limited to a 6-mile run, which was insufficient to warm up to efficient operation. No changes were made in the system in any way. We simply changed from kerosene to fuel oil and then started immediately, showing that almost any kind of fuel can be used without very much alteration. Many times I have changed from kerosene to gasoline, then to

ADDITIONAL RUN NO. 4

Total distance, miles	30.9
Elapsed time, hr.	1.6
Atmospheric temperature, deg. fahr.	40
Average speed, m.p.h.	19.3
Fuel used, gal.	4 2/3
Miles per gallon of fuel	7
Water used, gal.	1

(*Concluded on page* 162)

FIG. 9—THE LOADED TRUCK WHICH WAS USED IN THE TESTS

Automotive Obligations Toward Highway Development

By H. W. Alden[1]

Annual Meeting Address

In opening this Highway Session, I wish to bring to your attention very clearly and emphatically the responsibility of the automotive industry for some things besides the actual building and selling of motor cars. We all know that the progress of civilization can be measured very largely by advances in means of communication. The transfer of thoughts and messages by wire and wireless has made wonderful advances of a fundamental and revolutionary nature in recent years. On the whole, the transportation of things from place to place has not made such strides. This is fundamentally due, I believe, to the fact that practical performance can be developed in laboratory investigations better in the former case than in the latter.

In electrical matters, such as the telephone and telegraph both with and without wires, the companies controlling the work have exhibited great foresight and shown great energy in all its phases. Perhaps it has been necessary to their very life that they should do so, but it is a fact that they have done so. This is far from true in the automotive industry. We have been concerned mostly with the actual development and production of the motor car and, as an industry, have stopped there without developing those allied activities which are vital to the long-time success of the business. Our railroads are a good example to follow in principle. The roadbed and the equipment operating on that roadbed have been improved and developed hand-in-hand by the same general guiding influences. The wonderful advance in both in the last 20 years is due fundamentally to this unified control of these two elements.

In the matter of highway transport, we find a different condition. It is true that today we have far better highways than formerly, but I believe the ratio between the demand on the highways and their ability to meet that demand has, on the whole, gone down rather than remained constant. The increase in numbers and capacity of motor cars has been greater than the extension and improvement of highways. It is my opinion that the responsibility for this rests squarely on the shoulders of the automotive industry itself. It is easy to criticise the highway engineer, but I venture to assert that the average highway engineer can come nearer qualifying as an automotive engineer that his automotive brother can as a highway engineer. If I should ask those present to stand up who have given serious thought to highway design and construction, not many chairs would be vacated. We cannot continue increasing the number and capacity of motor cars for our own profit and shirk the responsibility of helping in highway development. That is one of the facts I want to emphasize as forcefully as I know how. The long-time success of our business is inextricably interwoven with highway development. Unless this situation is more clearly understood and its lessons learned by the industry, then the industry will not advance as it might.

My sympathy lies very largely with the highway engineer. Our engineering schools have, on the whole, been asleep and have failed to provide instruction in this work. Consequently, the highway engineer has had to blaze his own trail until very recently. Considering his handicap of political jobbery, it has been an uphill task. Until very recently, I repeat that the automotive industry has been occupied too much with making money and not enough with those allied activities which, for its own good, should have had its hearty cooperation all the time.

Merchandise transportation depends not only on cars and roadbeds, automobiles and highways, boats and waterways and, I might add for the future, airplanes and blue sky, but on the manner of use of these agencies. Here again we can learn a lesson from railroad experience. In the past the development of freight terminals and rail transportation has been under the same general guidance and the development of the two has been consistent and logical. The recent projection of the automobile into the transportation field has made possible wonderful changes in the methods of distribution of all commodities, but here again the automotive industry, as a whole, has neglected its full responsibility. It has failed to shoulder this responsibility for the correct use of the new instrument which it has produced, and for the proper correlation of it with previously existing instruments. I believe we are emerging gradually from our fools' paradise of money-making into a realization of this larger responsibility. How the railroads, highways and waterways can be best joined together in the general function of merchandise transportation is worthy of any man's time and intensive study. The correct solution and the proper arrangement of these three agencies will have a wonderful effect on the future of our industry.

Freight cars average little better than 25 miles per day, due to terminal delays which could be eliminated largely if the motor trucks and railroads were in proper relation. This daily average could be lifted easily to 75 or 100 miles if the inefficiency of present terminal methods were eliminated. This is no idle dream. The basic trouble is that railroads are doing an enormous amount of less-than-carload, short-haul work for which they are not so well equipped as is the motor truck. The average distance that each ton of freight is hauled by rail is less than 200 miles, due to this large amount of short-haul tonnage. A proper re-arrangement wherein the motor truck would do the short-haul and the less-than-carload work and the railroads the long-haul work would give us a regular freight transportation more speedy than today's average express shipments and at a cost far less than anything dreamed of today. However, I have seen little indication of study of this problem by the automotive industry as a whole, or of cooperation with the railroads in its solution, until very recently. We cannot pass

[1]M. S. A. E.—Vice-president, Timken-Detroit Axle Co., Detroit.

the blame on to the railroads. The responsibility is our own. It is a challenge to the brains of the automotive industry and, unless we get busy and assist in the solution of this problem, the progress of the truck industry will be slow where it might be rapid. The details of these questions are numerous, but they are not difficult of solution. They must, however, be honestly faced and understood. Then, if honestly attacked, the results will revolutionize our transportation business.

I am fairly well acquainted with what our industry has done in the fields of highway development and merchandise transportation, but I repeat that what has been done is only a drop in the bucket. I am greatly pleased that our Society is showing signs of life in these two directions, as they are at the very foundation of our future success and expansion. It behooves every automotive engineer to devote a goodly share of his time to studying these two questions. I hope what I have said will direct our attention more and more to these fundamental problems, the solution of which is as much our responsibility as it is that of the railroad and highway engineers.

PRESIDENTIAL ADDRESS OF J. G. VINCENT

(*Concluded from page* 100)

construction, improved installation of powerplant auxiliaries and cleaner-cut plane design, accomplished by the elimination of wires to a reasonable extent and the substitution of inherently rigid structural elements. The reduction of head resistance resulting from these improvements will admit of higher speed with the same power, or the same speed with reduced power, or advantage may be taken of securing a higher ratio of useful load. We should encourage in every possible way the construction of additional landing fields which essentially must precede the development of commercial aviation on an extensive scale.

The fuel problem has not as yet affected airplane engine design materially, since the limited quantities of high-test fuel required at present for aircraft operation are easily obtainable. However, it would appear that ultimately the same fuel would be used in both cars and airplanes.

In the matter of lubricating oil, airplane engines are now satisfactorily handled with mineral oils of somewhat heavier body than used for ordinary automobile engines.

Perhaps the most conspicuous tendency in airplane engine design at the present time is to pay more attention to efficient operation at altitudes and under reduced throttle conditions obtaining during average flights. This involves in some cases special precautions against running wide-open near the ground, except for short periods with the aid of special fuels to guard against preignition and detonation. In this manner it is possible to effect considerable savings in fuel consumption at altitudes together with an increase of available power under normal flying conditions.

A STEAM POWER AUTOMOTIVE TRUCK

(*Concluded from page* 160)

fuel oil and after that to a mixture of the three fuels, without any noticeable change in operating performance.

Fig. 9 on page 160 shows the truck equipped with body and loaded. It will be noted that pneumatic tires are used. This truck has been run at 35 m.p.h., which was by no means the limit of its speed.

Table 6 gives the mileage per gallon of fuel and per gallon of oil obtained with several different types of truck in tests conducted by a prominent oil refining company.

Table 6—Mileage per Gallon of Fuel and of Oil

Type of Truck	Capacity, Tons	Mileage Obtained per Gallon	
		Gasoline	Oil
Bourne	2	4.72	91.3
White	2	5.21	45.3
Packard	3	4.30	128.5
White	5	3.14	20.1

Future Development

It is possible to equip this truck with some disengaging clutch, for coasting, that will increase the fuel and water mileage greatly.

We have a process for using steam to propel a truck or an automobile that will give a fuel mileage on our truck of from 18 to 20 miles per gal. of kerosene or fuel oil, if the details can be worked out in a practical way. It is now in process of development and has been built, but it is still in the experimental stage.

PROPERTIES OF WHITE-METAL ALLOYS

(*Concluded from page* 154)

tests at temperatures up to 100 deg. cent. (212 deg. fahr.) are given for five typical white-metal bearing alloys, including three tin-base alloys, one lead-base and one intermediate alloy, which show that the tin-base alloys maintain their properties the best at elevated temperatures.

The results of tests are given which indicate that up to 5 per cent of lead in a high-grade babbitt does not affect the yield-point or ultimate srength at 25 or 75 deg. cent. (77 or 167 deg. fahr.).

The yield-point of tin-base alloys is not affected by heating for six weeks at about 100 deg. cent. (212 deg. fahr.), but the yield-point is lowered in the lead-base alloy by heating for two weeks at about 100 deg. cent. (212 deg. fahr.).

Highway Road-Construction

By William E. Williams[1]

Annual Meeting Paper *Illustrated with* Photographs and Drawings

ONLY three road surfaces have given satisfaction for automobile traffic; asphalt, brick and concrete slabs. Thus far the concrete-slab surface is the only one worthy of consideration for such traffic. Many people think that the roadbed should be elastic and that the asphalt and the brick surfaces furnish

Fig. 1

elastic conditions. Experience has proved that an asphalt surface will not stand up under heavy truck traffic. The brick surface comes nearer to the desirability of the concrete-slab surface than the asphalt.

The idea that an asphaltic surface is necessary for the riding qualities and preservation of the vehicle is an old one; it has been thrashed out in railroad service and other lines with the result that elasticity in a roadbed is found to have been a mistaken idea. The best roadbed is an absolutely solid one, with as straight a surface as can be obtained. One of the examples of an old theory in regard to elasticity is found in stamp mills that reduce ore. It was believed for generations that a stamp mill should be founded on a heavy timber grillage having masonry underneath, the timber furnishing, as it were, an elastic shock cushion for the stamp-rods. It appeared that, whenever these stamps were founded on solid masonry, the stamp-rods would crystallize and break. The builders of these mills specified in old days that their guarantee would not follow the mill unless it was founded on a timber grillage. This method was discarded by engineers in the copper country, who built heavy masonry foundations with the least possible elasticity and made the stamprods of steel. Then it was found that this type of stamp mill was better than one having an elastic timber-grillage base-construction. The stamprods did not crystallize and break when made of steel.

The road surface should be as nearly rigid as it is possible to make it. It is a mistake to make a road surface which is expected to bend under the movement of traffic, even in the least possible amount that is preventable; for in this way the road is destroyed. The asphalt-surface road, or a brick-surface road, must have a concrete base. The asphalt and brick surfaces aid the concrete base but slightly in sustaining beam loads, or in providing a wider distribution of the load over the surface soil or sub-base of the road; whereas, if the equivalent of the thickness of the asphalt and the brick, and particularly the cost of laying those materials, is expended in producing an extra thickness of the concrete slab, a stronger load-sustaining surface will be obtained than it is possible to get at the same cost with any supplementary facing such as asphalt or brick. It costs more to lay the asphalt or brick for a given depth than it does for the same depth of concrete. A brick surface is substantially 4 in. in depth and is supported by 4, 5 or 6 in. of concrete base, making a total depth of not less than from 8 to 10 in. The relative strength as a beam of that road surface is substantially limited to the thickness of the concrete underneath the brick, say 6 in. as a maximum. A concrete slab of the same relative depth as 4 in. of brick and 6 in. of concrete, would amount to 10 in. The relative load-sustaining capacity as a beam construction would be 36 for the brick surface, being the square of the depth of 6 in., which is the thickness of the concrete base; it would be 100 for the concrete slab, being the square of the depth of the concrete slab. Thus, both brick and asphalt have no chance of being competitors for service on a motor-truck highway. The concentrated loads placed upon the wheels when the heaviest trucks are considered run as high as from 4 to 8 tons under a single wheel. This is on an area perhaps not greater than $\frac{1}{3}$ sq. ft. The

Fig. 2

[1]M.S.A.E.—Consulting engineer, Chicago.

FIG. 3

crushing bearing value of the concrete at 3000 lb. per sq. in. is able to carry the load, but the bearing value for many subsoils is not.

BEARING VALUE OF SOILS

From a standpoint of furnishing foundations for buildings, which are static loads instead of being vibratory, the bearing values of soils are rarely ever estimated for more than 5000 lb. or 2½ tons per sq. ft. for the best types of soil. For vibratory loads, such as the sub-bases of hard roads, an average bearing should not be taken at more than 1 ton or 2000 lb. per sq. ft. With the same soils and bad weather conditions 1000 lb. per sq. ft., or less, is all that the soil will stand. The moisture variations in sub-base soils for roads make bearing values appear fickle indeed, ranging from 2 to 10 lb. per sq. in. in some tests made on an Illinois road sub-base and thus ranging from 288 to 1440 lb. per sq. ft., so, the bearing value is illusive and is not safe at over 1000 lb. or less per sq. ft. in Illinois.

Solid rubber tires are rated to carry 800 to 900 lb. per lineal inch of width of tire, on the largest sizes. A 14-in. tire bearing 900 lb. per in. amounts to a total load of 12,600 lb., or 6½ tons under a single wheel. The

FIG 4

heaviest makes of large trucks that are actually used often exceed that bearing load per wheel. This tire load of 12,600 lb., disregarding the excess often met with, must be supported by the sub-base of the roadway at the worst season of the year. This is when the ground is wet and the frost is coming out, a time that the sub-base should not be required to support a load of over 2000 lb. per sq. ft., or less; so, to take care of this 12,600 lb. on that wheel, the concrete slab should be able to distribute it over an area of at least 6 sq. ft.

If the wheel gets near the edge of the slab of the concrete, it amounts to making the slab transmit the load in a semi-circular area having a radius of 4 ft. On crossing an expansion joint or cross crack, the wheel load will then be carried, as it were, by the point or apex of a triangular section, making the concrete slab distribute its load from a point or apex of a right-angle corner over the area of 6 sq. ft. already mentioned, which would result in a right-angle triangle, or its equivalent of about 3½ sq. ft. on the side. Assuming that there is underneath this triangular slab a soil bearing of 2000 lb. per sq. ft., there will result strains along the hypothenuse side of this triangle on the extreme fibers of the concrete in tension of 380 lb. per sq. in. for 6½-in. slab and 250 lb. per sq. in. for 8-in. slab. At a soil bearing of 1000 lb. per sq. ft., the better average for bad weather conditions of subsoil, the maximum fiber stress for 6½-in. slab is about 600 lb. per sq. in. and for an 8-in. slab 400 lb. per sq. in. No concrete which is not reinforced will withstand these stresses. Good concrete in tension runs from 250 to 300 lb. per sq. in. Many slabs are seated so that there is a slight movement or vibration of the slab at every load that passes and, with heavy loads, this vibration packs down the subsoil until there is an actual void for a considerable distance underneath the slab. The slab then breaks and this is what occurs in most of the failures. The photographs shown in Figs. 1 to 4 are typical of just such breaks, which in our district have furnished the bulk of the failures in concrete roadways, and Table 1, in connection with Fig. 5, shows the stresses involved as already described.

CORRECTING ROAD FAILURES

Many different remedies have been offered for correcting road failures. One of them is that on clay or aluvial-soil sub-bases there should be placed a cushion 3 or 4 in. thick, of porous material such as sand or cinders, that will permit the sub-base to drain out and remain in a more uniform condition under the varying weather conditions. In some localities the sand sub-base seems to indicate that this is the correct thing to do. In Illinois, however, we have roads that have sand sub-bases that have cracked as badly after a time as the other bases did. It is my opinion that the cost of this sand should be expended in providing a thicker slab of concrete. A sand sub-base 3 in. thick might cost approximately the same as another inch in depth of concrete slab.

If the concrete slab is 6 in. thick and the sand base 3 in., by leaving off the sand base we might make the slab 7 in. The relative beam strength of the concrete slabs would then appear as 36 for the 6-in. and 49 for the 7-in. slab, a gain in strength for the 7-in. slab of one-third, measured in the value of a 6-in. slab. A slab 8 in. thick would represent a beam strength of 64 compared with a beam strength of 81 for a 9-in. slab. Here again more than a one-quarter increase in strength is obtained by an extra 1 in. of depth. In some instances

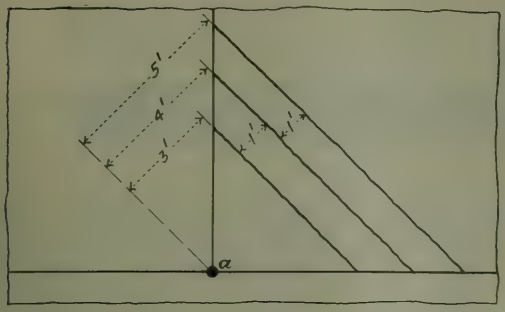


FIG. 5

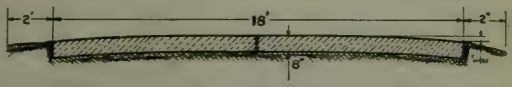


FIG. 8

block before mentioned that is the best form in my opinion.

Fig. 7 represents a typical 8-in. concrete-slab road as now built. A better road, in my opinion, is shown in Fig. 8, where the slab is divided along the middle of the road to let each side spring by itself under heavy loads. Fig. 9 shows the provision for one longitudinal central drain, cared for by cross-drains at intervals. This is better construction than two side-drains. Fig. 10 is better construction than that shown in Figs.

TABLE 1—LOADS AND STRESSES ON TRIANGULAR CONCRETE SLABS[2]

			Pressure between Concrete and Subsoil			
			None		1,000 lb. per sq. ft.[3]	2,000 lb. per sq. ft.[3]
Load at a, Fig. 5, lb.	Length of Arm, ft.	Concrete Thickness, in.	Stress, lb. per sq. in.	Deflection, in.	Stress, lb. per sq. in.	Stress, lb. per sq. in.
9,600	3	6.5	680	0.054	468.0	2.56
	4	6.5	680	0.097	302.0	[4]
	5	6.5	680	0.151	90.0	[4]
	3	8.0	450	0.029	310.0	170
	4	8.0	450	0.052	200.0	[4]
	5	8.0	450	0.081	59.5	[4]
12,600	3	6.5	895	0.071	682.0	380
	4	6.5	895	0.127	516.0	[4]
	5	6.5	895	0.198	302.0	[4]
	3	8.0	590	0.038	450.0	250
	4	8.0	590	0.068	340.0	[4]
	5	8.0	590	0.106	200.0	[4]

[2]Modulus of elasticity equals 2,500,000 lb.

[3]Assuming that no deflection is necessary to obtain the 1000 lb. per sq. ft. pressure, the bending moment for 1000 lb. and for 2000 lb. per sq. ft. pressure between the concrete and the subsoil is reduced an amount equivalent to a load of 1000 lb. or 2,000 lb. per sq. ft. on the concrete, as the case may be, over that under the heading "None."

[4]Concrete at 2000 lb. per sq. ft. pressure would carry the load.

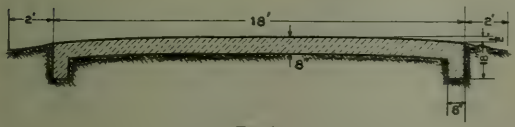


FIG. 6

it is desirable to make the slab on the edges with a rib or a curb section extending down into the soil to stiffen the edges of the slab and shut out the excess moisture that runs over, seeps down under the base and softens the soil sub-base. This edge or under supporting curb block, when made an integral part of the slab itself, is a good investment in many cases. This feature is worthy of consideration for general adoption. It is illustrated in Fig. 6, which shows the side integral curb

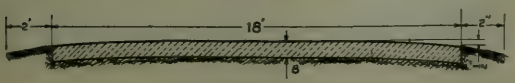
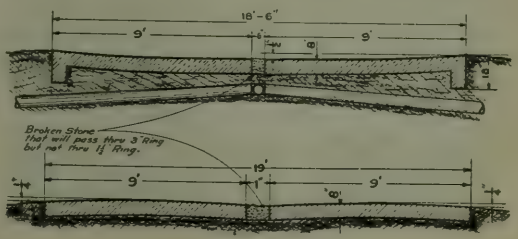


FIG. 7

7 and 8, for it allows a central moistening of the subbase as well as at the sides and provides for uniform settlement of each side slab. Fig. 11 is a suggestion for a steel-surface road having flat steel wheel-tracks 18 in. wide, imbedded in concrete slabs. The steel tracks are inverted channels and the concrete slabs are narrow and ballasted with broken stone, which permits the slabs to be surfaced up like a railroad track. The cost of this appears prohibitive, but one cannot tell what experience



FIGS. 9 AND 10

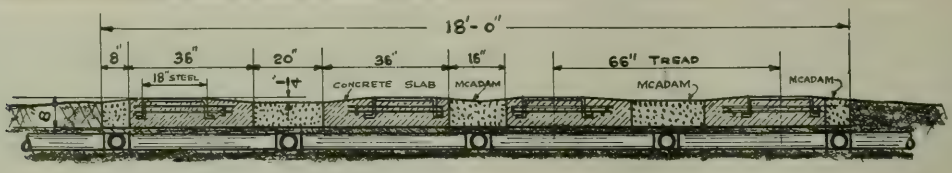


FIG. 11

may lead to. Fig. 12 shows the trend of thought toward a steel-surface road.

REINFORCEMENT

Reinforcing with steel in a concrete road slab is of doubtful value, except in special cases. If reinforcement is applied only sparingly it is of little or no value; in fact, I think it results in injury to the concrete. Reinforcing should be omitted unless sufficient steel is put in the top and bottom of the slab to permit the reinforcing to carry the load at low metal-fiber stresses, so that the stretch of the reinforcing under the maximum fiber stresses will not exceed the elastic limit of the concrete. If, however, the reinforcing is strained up to permissible limits for the steel, the stretch in the steel before those limits are reached breaks the reinforcing free of its bond in the concrete and the latter will crack.

There are certain places where it is well known in advance that the concrete slab will be required to act as a beam; for example, where an embankment is merged onto a solid abutment and it is certain that the soil or sub-base underneath the slab will sag away from the solid abutment. Reinforcing should be placed then on the bottom side of the slab, making this last slab a bridge from the mudbank to the solid masonry abutment. In such cases sufficient reinforcing can be used to make this slab safe. The cost of reinforcing, no matter how sparingly it is used in a road slab, can be better expended generally in providing a deeper concrete slab. Thus, the benefit of the square of the depth in the increased depth of the slab is obtained, making a better road than is obtained for the same money with reinforcing. Working this out in figures of cost and strength of slab will show that this conclusion is correct.

THE ULTIMATE HIGHWAY

A concrete-slab road, about 8 in. thick and of a uniform depth across the road, perhaps with an increased thickness integral supporting curb-block on the edges in some locations, is the type of road that should be built in this country. If this road will not stand up, and it appears that it will not carry the maximum strains required by the heaviest trucks, then those heavy trucks must be denied the use of the roads. By roads, I mean country roads. The city pavements are in a different situation, because they extend from curb to curb and no water is expected to seep through and soften the sub-bases. The heavy traffic does not run generally on the edges of the slab but over the body thereof; so, owing to the protected sub-base, heavier loads can be carried on city pavements than can be expected to be carried on a country road. The needs of the automobile world and the general welfare of the country are that we should have the greatest amount of hard roads possible, to be obtained in the shortest space of time and with the least expense. It is better for the roads to be limited to the use of vehicles that will not break down the average standard road than to be required to build a road for our excessively heavy trucks.

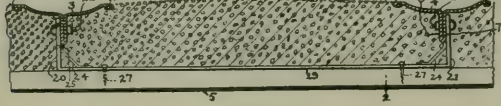


FIG. 12

When a road is built for the maximum load that the heaviest trucks are known to carry, then we will have limited to only a small mileage the ability of the country to furnish that type of road; whereas, with the other types of road, the mileage can be increased so that it will increase the use of automotive vehicles and furnish the demand for vehicles that the manufacturers want, even if in a few instances there is some hardship to the builders of some types of vehicle. In my opinion, the automobile vehicle world will profit by laws that prohibit anything above a 5-ton load and force trailers to take care of the heavy-weight loads. The maximum tire load of the maximum truck load is the factor to be considered, and not the weight per inch of tire. The concrete surface will withstand more per inch than will any rubber tire. It is the beam strength of the concrete slab that counts. In other words, the amount of load per square foot of area on the sub-base which the slab must distribute is what we have to look after.

IMPACT

Impact is much discussed and is likewise misunderstood. If the road and the tires are smooth and the road has no offsets, the greater the speed of the load over the road is, the less the damage will be. Gravity is a time factor. We remember that as boys we skated over thin ice. A speed of 10 m.p.h. is 14.66 ft. per sec.; at 20 m.p.h. it is 29.33 ft. per sec. Thus the force of gravity on the slab for a given second at 10 m.p.h. is spent on 14.66 ft. of length of the slab and at 20 m.p.h. on 29.33 ft.; so, with smooth surfaces, the speed is a secondary factor of destruction. With bumps in the road, tire speed is a serious factor of destruction. A brick surface cannot be commercially laid without having an infinite number of small offsets that produce impact remaining in its surface.

A speed of 10 m.p.h. is about 1/15 sec. and one of 20 m.p.h. about 1/30 sec. to 1 ft. of travel on the road. The acceleration of gravity will cause a drop of 0.87 in. in 1/15 sec. and 0.22 in. in 1/13 sec. Omitting the action of the springs, a wheel will travel downward off of an abrupt shoulder less than 1 in. in 1 ft. of road travel at 10 m.p.h. and less than ¼ in. at 20 m.p.h. However, the springs of a vehicle counteract this and produce impact of the wheels on the road in much shorter distances. Offsets of any kind are serious factors of impact and destruction.

I repeat that the money available should be made to build the greatest mileage of road that will induce the use of the largest number of automotive vehicles, even at the sacrifice of the heaviest ones.

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Chassis Design for Fuel Economy

By A. L. Putnam[1]

Annual Meeting Paper

As the engine is the most important unit of a complete automobile chassis, it has had a major share of attention in its development and it is considerably in advance of the rest of the machine as a result. This is true, notwithstanding the fact that great improvements in engine efficiency are not very evident when the engines are operated under normal conditions of service.

A 10 per cent more efficient engine placed in a motor boat, airplane or tractor is quite likely to preserve that characteristic, but in a passenger-car chassis it may be no better or even 10 per cent worse due to the wide variation of handling speed and load. All engines are now so good and reliable and require so little attention that a man looking after a car and attempting to keep it in condition for smooth operation spends hours on the other parts and units for every minute he spends on the engine. Also, when the car is put into service on the road, nearly all the attention of the driver and passengers is concentrated on the purely vehicular performance of the car with relation to the wide variety of road surfaces, and not on the engine performance. Consequently, for the passenger-car engineer, at any rate, improvements in the automobile as a road vehicle offer greater scope and reward than improvements in engines, particularly as all such improvements are reflected in direct proportion instead of being minimized by a score of adverse operating conditions.

Heavy Greases

The attitude has been common of not worrying about a fraction of 1 per cent loss here and there when such an enormous loss is pouring out of the exhaust pipe and radiator. These other varying and intermittent losses in the aggregate are not insignificant and when multiplied by millions of cars become tens of millions of gallons of fuel and oil. My aim is to call attention to some of them with suggestions as to means and methods of correction. The anti-friction bearings themselves give very little chance for any considerable improvement. But the practice of using a very heavy grease in the transmission and rear axle which solidifies at even a cool temperature from the standpoint of fuel economy and efficient lubrication is far from economical. This is particularly the case when the car is frequently stopped and started and used intermittently in very cold weather. Accurate data can, of course, be secured on this point by driving the transmission or the axle by an electric motor at different temperatures with heavy "dope" or thin engine oil as a lubricant and I am sure the results would be rather informing. The various very good and important reasons which have resulted in the building up of this heavy dope practice have so nearly disappeared that they can all be overcome. It is now perfectly possible to make and install gears which will pass as to sound even if not smothered by dope. It is also possible to construct properly vented transmission cases and differential housings which will hold thin oil with even less leakage than we have at present with the thick.

Dragging Brakes

The great congestion of traffic in cities, towns and in fact almost everywhere has brought about a very common custom of insistence on a brake adjustment which gives instant action with a very small pedal movement. This condition the external-band brake is a very poor instrument to fulfill. It is virtually impossible as a matter of common practice to adjust it closely enough to suit and still not drag some. As the quick brake must be had at any cost, the larger number are dragging. A dragging brake which does not heat enough to call attention to itself by developing excessive heat at a moderate speed still has a marked effect on the position of the throttle and is a very clever scheme to burn gas. Brakes are at this minute, I am sure, pulling from a mere fraction to several horsepower per pair out of the majority of cars equipped with them. The internal-expanding type of brake is much better adapted to extremely close adjustment without dragging and the heat it generates expands and contracts the drum in the right direction with relation to the shoes instead of the wrong direction as in the case of the external-band brake.

You probably all recollect statements which have appeared from time to time in the press by enthusiastic writers that we no longer have horseless carriages but something entirely different and on a much higher mechanical plane than a road vehicle. I have implicitly believed this; I was undeceived this summer in Cincinnati. The company there which transports passengers from one railroad station to the other is not yet fully motorized. It has some light motor buses and some horse-drawn buses which operate at equivalent speed over a vile series of Belgian-block-paved streets. I made the trip one way in a motor bus and the other in the horse-drawn bus. The trip in the latter was so much more smooth and comfortable even with its steel tires and freedom from the bumping, pitching, and sidesway that the pneumatic-tired motor bus had, that after alighting I compared the two vehicles and their construction. This inspection convinced me that we had stuck pretty closely to the old horse carriage and were using all its old stuff with a few extras of our own added for good measure.

Relative Motion of Parts

The main extra the automobile has incorporated is really an extra vehicle. There is one vehicle consisting of wheels, axles, springs, torque-rods, truss-rod, etc., disposed so as to permit of the maximum amount of displacement or separation from the engine frame and body. This engine is asked to transmit its power smoothly and quietly to the wheels and axles which are constantly trying to escape from it and at times taking a very considerable degree of variation in position with relation to it. All these vagaries the engine is asked to furnish the power to produce and it takes some power to lift a 2000-lb. body and load 3 in. up and 4 in. down from the nor-

[1] M.S.A.E.—Research engineer, Detroit Pressed Steel Co., Detroit.

mal position and keep on doing it. Just hitch up an engine on the rear end and let it do that one job only. I am sure the power required is sufficient to measure. It was found out centuries ago that horses could not do it and do anything else. Because we have a source of power that does not sweat and lather is not a reason we should continue present practice.

The excessive amount of motion between the engine and the axle, of course, causes a loss of power and fuel in a minor degree due to joint angularity which produces wear; it takes power to produce wear. I think that this excessive amount of movement, no matter how smoothly accomplished, is not, strictly speaking, a comfortable one for the passengers, and know that it is very fatiguing for the driver, increasing greatly the strain of guiding the vehicle.

We have all probably noticed the small power trip-hammers with the hammer mounted on a leather strap that is shackled to a semi-elliptic spring and the whole head moved up and down by a crank. We have also noticed how the hammer keeps on striking energetically long after the crank has ceased to move it. This trip-hammer is a very good illustration of the action of the axles and springs under the modern automobile and the powerful reactions they give; the engine producing these reactions by furnishing the power to roll over the uneven road surface.

As the weight of the parts in question is on the average about one-quarter of the total weight, they are able to cause considerable disturbance in the smooth operation of the vehicle. This fact is, of course, so generally appreciated that many serious endeavors are made to reduce appreciably the weight of these unsprung parts and by so doing decrease the effect of their action and reaction. These efforts undoubtedly have good effect when they are carried far enough to make an appreciable change in the proportion of sprung and unsprung weight.

Effect of Tire Sizes

No matter what is done to decrease the unsprung weight, the effort starts with a fundamental handicap due to a certain other series of standards. This was called very forcefully to my attention by the declaration of the Tire and Rim Association that the 3½, 4, 4½ and 5-in. tires cover adequately the passenger-car field. This is true no doubt in a narrow sense, but from the standpoint of fuel economy and vehicle efficiency is the pneumatic tire doing all it possibly can? The pneumatic tire is one of the main factors in the success of the passenger automobile. If this tire is such a good thing, why not have a little more of it? Why not give it a larger opportunity to show its worth and itself absorb a larger proportion of the shocks, and give better traction?

Years ago the taximeters came off the rear wheels by law because the rear wheels could accumulate mileage at an astonishing rate. They, of course, use fuel to do it; all rear tires are making much more mileage than the vehicle on some classes of roads and there are thousands and thousands of miles of such roads on which the skipping and spinning is so marked as to affect the throttle position for a certain speed enough to call this to the attention of a not very observing driver. This condition is wasteful of fuel and of the rubber tread as well. The main factor in producing this loss of traction and violent action and reaction on the unsprung weight is the proportional tire cross-sectional size and accompanying air pressure for a given load.

The necessary high air pressure to support the load without injurious deflection of the tire makes the tire so hard and produces such violent reaction when hitting inequalities in the road that the spinning and chattering of the rear tires constitute on many classes of road a very large item of fuel loss, tire destruction and speed. The exceedingly hard small tire is also the instigator of the use of the complicated heavy and highly flexible spring suspension. Given a series of tires of the same outside diameters but considerably increased cross-section for the same load, the air pressure can be cut down safely and a condition produced in which a larger proportion of shocks is absorbed at the source, less slipping and spinning of wheels occur and better traction for starting, running and braking without putting the spring suspension into play so much, is secured.

In fact it is perfectly possible to carry this idea far enough to eliminate the springs entirely and simply provide for the horizontal displacement of the front wheels with relation to the rear pair. When this is done the unsprung weight factor will have disappeared, as all the weight is sprung weight and completely tied together without movement. The wheels move with the body and the body with the wheels.

At present we seem to be accepting as gospel the statement that the present tire sizes as put forward are the last word as regards pneumatic-tire equipment, when a little thought and even less science can prove them as only the beginning of the real use of pneumatic tires.

HECTER AND AVIATION GASOLINE COMPARED

THE National Advisory Committee for Aeronautics, Washington, has issued Report No. 90 containing a comparison of hecter fuel with export aviation gasoline. This fuel is one which has been developed in response to the demand for fuels that are capable of operating under compressions which are too high for gasoline. This fuel will operate at compression ratios up to at least 8.0 without preignition or "pinking." The hecter fuel supplied by the Bureau of Mines for use in these tests was a mixture of 30 per cent benzol and 70 per cent cyclohexane having a low freezing point and distilling from the first drop to 90 per cent at practically a constant temperature that was about 20 deg. cent. (68 deg. fahr.) below the average distillation temperature of the export aviation gasoline with which it was compared.

The comparison of the performance of the two fuels embodied in the report was made with a Liberty 12-cylinder aviation engine supplied with special pistons giving a compression ratio of 7.2 to 1, the compression pressure measured by check-valve gage being 170 lb. per sq. in., in the altitude chamber at the Bureau of Standards, Washington, duplicating altitude conditions up to about 25,000 ft. except that the temperature of the air entering the carbureter was maintained nearly constant at about 10 deg. cent. (50 deg. fahr.). Stromberg carbureters were used and were adjusted for each change of fuel, speed, load and altitude so as to give the maximum possible power with the least fuel consumption for this power. The tests covered a speed range of 1400 to 1800 r.p.m. and the results of these experiments, a preliminary account of which was published in the July, 1920 issue of THE JOURNAL on page 110, show that the power developed by hecter fuel is the same as that developed by export aviation gasoline at approximately 1800 r.p.m. at all altitudes.

A copy of the report can be obtained upon request from the National Advisory Committee for Aeronautics, Washington.

Standards Committee Meeting

THE meeting of the Standards Committee was convened on the morning of Jan. 11 in the Engineering Societies Building, New York City, with Chairman B. B. Bachman presiding. After declaring a quorum present, Chairman Bachman addressed the meeting substantially as follows:

The printed pamphlets that were mailed to the members of the Standards Committee and the Society contain the reports of 12 Divisions of the Standards Committee on 35 subjects completed by the several Divisions since the meeting held at Ottawa Beach, Michigan, last June.

I think that everyone who has taken part in the Standards Committee work thoroughly appreciates its importance. Those who have not taken part in this work meet certain conditions from time to time in the conduct of their business that indicate the necessity for standardization. Probably they have never thought of it before, and it is a customary human failing not to do so until one is forced to meet a difficult situation. Frequently it is not until then that the value of or necessity for standards is appreciated. There are several ways in which the work of the Standards Committee can be enhanced. I think that in general the work of the Divisions is excellent; the meetings are fairly well attended, the amount of thought that is brought to bear on the reports is adequate in most cases, but unfortunately in many instances it stops at that point. The Divisions' recommendations are sent to the Standards Department of the Society where they are tabulated, checked and typographical and other errors corrected so far as possible, but the Standards Department cannot be expected to check matters a knowledge of which is obtained only by experience.

The Divisions' Reports are then submitted to the Standards Committee and usually there are matters of sufficient importance to a large enough number of members to result in discussion being had, but unfortunately a considerable amount of our work is done without sufficient attention being given to it at the Division and Standards Committee meetings.

Immediately following the Standards Committee Meeting, the Divisions' Reports are submitted to the Council and are considered only as a formality in most instances. From time to time, however, subjects come up which the Council deems it wise to refer back to Division for reasons of policy. The Council has never taken the position of acting as an arbitrary body in any sense in connection with the work of the Standards Committee and I think this policy will not be changed.

Presentation of Standards Committee reports to the Society in meeting assembled has become in later years largely a perfunctory matter; the business sessions in connection with which these reports are made are filled with important work, the time is limited and the attendance is relatively small. As a result, the reports have usually been presented by title only by the Chairman of the Standards Committee, and little or no time has been taken for discussion of them. I do not know that this can be changed, by reason of conditions such as I have outlined.

To remedy this condition as much as possible we have in recent years adopted a policy of submitting the proposed standards for letter ballot of the voting members of the Society but unfortunately the returns of these letter ballots are relatively small, amounting to a maximum of some 10 or 12 per cent. Still, after subjects have been approved and adopted, it has been found in a number of instances that things have been done which in the minds of some of our members should not have been done, and in many instances they have had good reasons for so thinking. The trouble has been that they did not take the proper steps at the proper time to have the proposed standards as complete or practical as desirable.

The reason for referring to this matter now is that I desire to appeal to all the members of the Standards Committee who appreciate the importance of its work and to urge them to act as missionaries among their acquaintances in the industry and the membership of the Society to see that the report submitted for letter ballot, as it appears in THE JOURNAL of the Society after it has been passed upon by the Standards Committee and Council, receives adequate consideration and attention by those who are qualified to pass on it and by those who are interested in any of the recommendations that are proposed for adoption. There is no other one thing that I know of that can be done by the members of the Standards Committee that will enhance the work of the Society more than this in one of its most important activities.

The reports as submitted by the several Divisions were presented by the Division Chairmen, and are here given in the form approved by the Standards Committee and the Council.

AERONAUTIC DIVISION REPORT

(1) *Turnbuckles*

During the period of the war the Society, in cooperation with the Bureau of Aircraft Production and the Navy Department, developed and adopted the present S.A.E. Recommended Practice for Aeronautic Turnbuckles printed on pages 45u to 45uj, S.A.E. HANDBOOK, Vol. I (old edition). The Bureau of Aircraft Production, specification No. 25,500, which corresponded with the S.A.E. Recommended Practice, was subsequently changed somewhat by adding the 800 lb. size and more complete tolerances for all sizes, as given in the latest B.A.P.

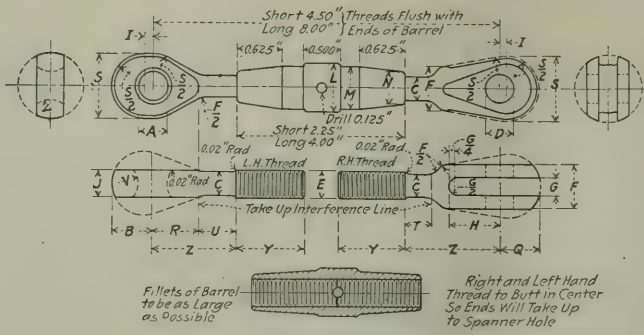
THREAD AND BARREL DIMENSIONS

S.A.E. Size	Threads	Shank Pitch Diameter In.		Barrel Pitch Diameter In.		Barrel			Strength in Pounds
		Max.	Min.	Max.	Min.	L +0.005 −0.005	M +0.005 −0.005	N +0.005 −0.005	
[illegible]	6-40	0.1228	0.1211	0.1235	0.1218	0.250	0.219	0.188	800
[illegible]	10-32	0.1707	0.1688	0.1716	0.1697	0.375	0.281	0.250	1600
21	12-28	0.1938	0.1918	0.1948	0.1928	0.375	0.328	0.281	2100
30	¼-28	0.2278	0.2258	0.2288	0.2268	0.438	0.391	0.328	3200
46	5/16-24	0.2834	0.2843	0.2875	0.2854	0.500	0.438	0.406	4600
61	3/8-24	0.3489	0.3468	0.3500	0.3479	0.625	0.594	0.469	6100
80	3/8-24	0.3489	0.3468	0.3500	0.3479	0.625	0.594	0.469	8000

All dimensions in inches.

specification No. 25,500-B, issued Jan. 25, 1919. The B.A.P. specification is more complete and is believed to be more generally followed in production.

Materials.—Barrels shall be made of brass in accord-



TURNBUCKLE DIMENSIONS

S. A. E. Size[1]	Threads	EYE AND FORK ENDS C +.006 −.000	E	I +.010 −.000	S +.010 −.010	Y +.047 −.047	Z +.031 −.015	EYE END A +.010 −.000	B +.010 −.010	J +.010 −.010	R +.010 −.010	V +.010 −.010	FORK END D +.010 −.000	F +.010 −.005	G +.010 −.000	H +.010 −.010	Q +.010 −.010	T +.005 −.000
8 SF	6-40	.094	.138	.031	.375	.375	1.125	.188	.219	.125	.250	.094	.188	.250	.109	.375	.188	.630
8 SE	6-40	.094	.138	.031	.375	.375	1.125	.188	.219	.125	.250	.094	....	....	....	....	....	....
16 SF	10-32	.133	.190	.031	.500	.500	1.125	.219	.281	.188	.328	.172	.188	.313	.150	.469	.250	.520
16 LF	10-32	.133	.190	.031	.500	.500	2.000	.219	.281	.188	.328	.172	.188	.313	.150	.469	.250	1.385
16 SE	10-32	.133	.190	.031	.500	.500	1.125	.219	.281	.188	.328	.172	....	....	....	....	....	....
16 LE	10-32	.133	.190	.031	.500	.500	2.000	.219	.281	.188	.328	.172	....	....	....	....	....	....
21 SF	12-28	.155	.216	.031	.500	.563	1.125	.219	.281	.188	.328	.172	.188	.313	.150[A]	.500	.250	.500
21 LF	12-28	.155	.216	.031	.500	.563	2.000	.219	.281	.188	.328	.172	.188	.313	.150[A]	.500	.250	1.375
21 SE	12-28	.155	.216	.031	.500	.563	1.125	.219	.281	.188	.328	.172	....	....	....	....	....	....
21 LE	12-28	.155	.216	.031	.500	.563	2.000	.219	.281	.188	.328	.172	....	....	....	....	....	....
32 SF	¼-28	.189	.250	.047	.625	.625	1.125	.281	.359	.219	.406	.203	.250	.438	.203[B]	.625	.313	.310
32 LF	¼-28	.189	.250	.047	.625	.625	2.000	.281	.359	.219	.406	.203	.250	.438	.203[B]	.625	.313	1.185
32 SE	¼-28	.189	.250	.047	.625	.625	1.125	.281	.359	.219	.406	.203	....	....	....	....	....	....
32 LE	¼-28	.189	.250	.047	.625	.625	2.000	.281	.359	.219	.406	.203	....	....	....	....	....	....
46 SF	5/16-24	.243	.313	.047	.688	.750	1.125	.313	.391	.281	.469	.250	.313	.500	.203	.625	.344	.310
46 LF	5/16-24	.243	.313	.047	.688	.750	2.000	.313	.391	.281	.469	.250	.313	.500	.203	.625	.344	1.185
46 SE	5/16-24	.243	.313	.047	.688	.750	1.125	.313	.391	.281	.469	.250	....	....	....	....	....	....
46 LE	5/16-24	.243	.313	.047	.688	.750	2.000	.313	.391	.281	.469	.250	....	....	....	....	....	....
61 LF	⅜-24	.256	.375	.063	.750	.875	2.000	.344	.438	.281	.500	.313	.375	.563	.203	.750	.375	2.050
61 LE	⅜-24	.256	.375	.063	.750	.875	2.000	.344	.438	.281	.500	.313	....	....	....	....	....	....
80 LF	7/16-24	.306	.375	.063	.875	.875	2.000	.375	.500	.328	.625	.375	.375	.563	.266	.875	.453	1.906
80 LE	7/16-24	.306	.375	.063	.875	.875	2.000	.375	.500	.328	.625	.375	....	....	....	....	....	....

[1]The letters indicate the following: SF, short fork and eye turnbuckle; LF, long fork and eye turnbuckle; SE, short double-eye turnbuckle; LE, long double-eye turnbuckle. When the eye end is used with a pin and clip the "A" dimension should be made equal to the "D" dimension in the fork end and radius "V" should not be used.

[A]Dimension G may be 0.109 with a lug having an ultimate strength of 125,000 lb. per sq. in.

[B]Dimension G may be 0.140 with a lug having an ultimate strength of 125,000 lb. per sq. in.

All threads U. S. Form.

ance with S.A.E. specification No. 73 or an equivalent alloy.

Shanks shall be treated to withstand the test loads specified.

Tests.—At least 2 per cent of all turnbuckles purchased shall be tested, and must withstand the tensile test load specified.

Each turnbuckle shank which meets the tensile test without breaking shall be held in a square-nose vise and bent through an angle of 90 deg., and must neither fail nor crack under this test.

Dimensions and Tolerances.—Turnbuckles shall conform, within the tolerances stated, to the dimensions specified.

Assembly.—Turnbuckles shall be assembled by selecting barrels and shanks to give a fit which will permit turning by hand.

All threads shall be greased and shanks completely screwed into the barrel before plating.

Finish and Inspection.—Unless otherwise specified, turnbuckles shall be copper plated after assembly and before inspection. They shall be thoroughly rinsed after plating to remove all traces of the electrolyte which may be in threads and barrel.

After inspection turnbuckles shall be either greased or coated with transparent lacquer as specified in the order. Turnbuckle shanks shall be thoroughly covered with non-corrosive grease, before shipment.

THE DISCUSSION

H. M. CRANE:—This has been a very quiet year in aeronautics as there has been really no aeronautic activity aside from supplying the Army and Navy. The result is that we are presenting a very short report. The first half of it refers to a simplification of the standard relating to turnbuckles which was adopted during the war.

J. L. HARKNESS:—The sizes recommended go up to an 8000-lb. turnbuckle, which is equivalent to a ¼-in. cable. I think it is only a question of time before it will have to be extended to include cables of larger sizes. We are developing larger machines now and it would be a good idea to have the standard extended to include turnbuckles to take 5/16 and ⅜-in. cables.

CHAIRMAN BACHMAN:—We will see that your suggestion is referred to the Division for attention.

S. TOUR:—I notice that under materials, the report reads, "Barrels shall be made of naval brass or an equivalent alloy." The Non-Ferrous Metals Division's report covers this, calling this alloy Brass Specification No. 73.

MR. CRANE:—This report was based on the Bureau of Aircraft Production's specification and I think it will be better so far as the Society is concerned, in view of the fact that it would make no actual difference, to change this reference to the S.A.E. Specification No. 73. That can be made an amendment to the motion to accept this report.

[A motion to that effect was made and carried.]

(2) *Special Report of the Aeronautic Division on the Regulation of Commercial Air Navigation*

Owing to the importance of outlining a definite program which would be of value in protecting commercial aviation against adverse legislation, the Council of the Society charged the Aeronautic Division some time ago with the preparation of a special report outlining desirable regulations for commercial air navigation.

The subject was referred to the Aeronautic Subdivision on Performance and Testing and a meeting was held at which the following recommendations were adopted:

A system of Federal registration of all aircraft for identification and in addition, licenses for certain specific purposes or uses should be adopted.

All aircraft carrying passengers for any purpose, or goods in commercial service, should be licensed by the Federal authority, which license shall indicate the aircraft licensed has complied with certain minimum requirements as to safety. By passengers is meant any person not a necessary member of the crew.

Any aircraft not coming under the classification in the previous paragraph may be licensed by the Federal authority even though not complying with the safety requirements, but only for restricted service with a view to minimizing danger to persons or property on the ground. This is intended to cover experimental and special racing aircraft as well as privately owned aircraft not used in commercial or Government service.

Minimum requirements cannot, even as regards the structural strength, be reduced to rules and figures capable of application in inspection except by persons of adequate engineering training in this field, and other necessary minimum requirements regarding safety of operation are the result of compromise and can be applied only by persons with trained judgment.

Any definite requirements or figures should not be written into legislation at this time, because these matters would be handled best by the regulation and ruling of the Federal authority which should be created by legislation.

Aircraft, which, in accordance with previous paragraphs, require a license, should be periodically inspected to insure that they continue to be in a safe operating condition.

MR. CRANE:—The remainder of the report of the Aeronautic Division is the result of very serious consideration by the Subdivision on Performance and Testing regarding the attitude the Society should take, either through this Division or in some other way, regarding restrictions on the operation of aircraft. You all realize that there will be eventually and probably soon legislation determining what are and what are not safe forms of aircraft for use in commercial pursuits. Many of those limitations will be of an engineering character and certainly constitute a subject of importance for consideration by the Society. The Subdivision did not feel that it had had time, or that the time has arrived, to go into all the details of so-called factors of safety and methods of test. It did feel, however, that the best opinion of the Subdivision regarding the methods of applying such tests and restrictions to machines of an experimental nature should be put before the Society. In other words, it is highly important to the Society, which wishes to encourage the development of experimental machines, that no legislation shall put too heavy restrictions on the flying of machines that have not been approved as being entirely safe, provided the tests are made by men who understand, in applying the tests, the risks they are taking.

We believe it is essential that the Society should back Federal legislation with all its strength as against State legislation.

> All aircraft carrying passengers for any purpose, or goods in commercial service, should be licensed by the Federal authority, which license shall indicate the aircraft licensed has complied with certain minimum requirements as to safety. By passengers is meant any person not a necessary member of the crew.

This is to safeguard the experimental machine in which the pilot may take up with him a mechanic or observer who is in the service of the designer and taking a risk which he thoroughly understands.

> Any aircraft not coming under the classification in the previous paragraph may be licensed by the Federal authority even though not complying with the safety requirements, but only for restricted service with a view to minimizing danger to persons or property on the ground. This is intended to cover experimental and special racing aircraft as well as privately owned aircraft not used in commercial or Government service.

This paragraph is plainly for the purpose of safeguarding experimental work and at the same time preventing the flying of experimental and possibly dangerous machines over thickly inhabited areas such as cities or towns, or any places of assembling.

> Minimum requirements cannot, even as regards the structural strength, be reduced to rules and figures capable of application in inspection except by persons of adequate engineering training in this field, and other necessary minimum requirements regarding safety of operation are the result of compromise and can be applied only by persons with trained judgment.

The Subdivision believes it is highly important to make it plain at this time that the ordinary political appointee cannot be expected to apply any rules that engineers can formulate for the products supplied; that is, when the engineers get together and determine what is a safe form of airplane, the result of their labor cannot be applied by technically untrained people. They must know a great deal more about the subject than in the case of the enforcement of import duties or internal revenue regulations or matters of that kind.

> Any definite requirements or figures should not be written into legislation at this time, because these matters would be handled best by the regulation and ruling of the Federal authority which should be created by legislation.

This paragraph states very clearly its reasons. The best engineering talent at the present time is not sufficiently expert to say what those rules should be, and it is far better that the regulating authorities should be able from time to time to make their own rules, provided such rules are made under the advice of experts.

> Aircraft, which, in accordance with previous paragraphs, require a license, should be periodically inspected to insure that they continue to be in a safe operating condition.

I have gone into this special report rather completely because it is a little out of the line of the regular standards work; in fact, it could hardly be called a Standards Committee report. It does however bring up very important questions that should have the attention of the Society and this is an excellent way of doing it.

This report may be considered as a form of further instructions to the Aeronautic Subdivision on Performance and Testing. There is outlined here a policy along the lines it is proposed to work in formulating any standards regarding performance and testing, and it is desirable to bring the matter before the Society to get approval or disapproval of the general program and policy.

Ball and Roller Bearings Division Report

(3) *Shaft and Housing Fits and Tolerances for Ball Bearings*

In order to obtain uniformity of practice as to shaft and housing fits and tolerances for ball bearings, a Subdivision was appointed to formulate a report to the Division. The recommendation of the Subdivision is based on the practice of grinding shaft-seats which is usually followed by automotive manufacturers and an analysis of the press-fit allowances recommended by manufacturers of ball bearings. This recommendation having met with approval by the Division is submitted for approval and publication as general information only. It is contemplated that should this practice become generally adopted by the industry, the Division will at a future time recommend its adoption as an S.A.E. specification.

The substance of the Division's original recommendation was approved by the Standards Committee and Council, and at the business meeting of the Society but the tables were referred back to the Division to be arranged to show the allowable variation in fit of the bearings on the shafts and in the housings as in the accompanying tables.

ALLOWANCES ON SHAFTS

Inside Diameter of Bearing				Fit on Shaft	
Nominal		Tolerances			
Mm.	In.	Plus	Minus	Tight	Loose
25	0.9843	0.0002	0.0004	0.0009	0.0002
30	1.1181	0.0002	0.0004	0.0009	0.0002
35	1.3780	0.0002	0.0004	0.0009	0.0002
40	1.5748	0.0002	0.0004	0.0009	0.0002
45	1.7717	0.0002	0.0004	0.0009	0.0002
50	1.9685	0.0002	0.0004	0.0009	0.0002
55	2.1654	0.0002	0.0004	0.0009	0.0002
60	2.3622	0.0002	0.0005	0.0010	0.0002
65	2.5591	0.0002	0.0005	0.0010	0.0002
70	2.7559	0.0002	0.0005	0.0010	0.0002
75	2.9528	0.0002	0.0005	0.0010	0.0002
80	3.1496	0.0002	0.0005	0.0010	0.0002
85	3.3465	0.0002	0.0006	0.0011	0.0002
90	3.5433	0.0002	0.0006	0.0011	0.0002
95	3.7402	0.0002	0.0006	0.0011	0.0002
100	3.9370	0.0002	0.0006	0.0011	0.0002
105	4.1339	0.0002	0.0006	0.0011	0.0002
110	4.3307	0.0002	0.0006	0.0011	0.0002
115	4.5276	0.0002	0.0006	0.0011	0.0002
120	4.7244	0.0002	0.0006	0.0011	0.0002
125	4.9213	0.0002	0.0006	0.0011	0.0002
130	5.1181	0.0002	0.0006	0.0011	0.0002
135	5.3150	0.0002	0.0006	0.0011	0.0002
140	5.5118	0.0002	0.0006	0.0011	0.0002
145	5.7087	0.0002	0.0006	0.0011	0.0002
150	5.9055	0.0002	0.0006	0.0011	0.0002
155	6.1024	0.0002	0.0006	0.0011	0.0002
160	6.2992	0.0002	0.0006	0.0011	0.0002
165	6.4961	0.0002	0.0006	0.0011	0.0002
170	6.6929	0.0002	0.0006	0.0011	0.0002
175	6.8898	0.0002	0.0006	0.0011	0.0002
180	7.0866	0.0002	0.0006	0.0011	0.0002
185	7.2835	0.0002	0.0006	0.0011	0.0002
190	7.4803	0.0002	0.0006	0.0011	0.0002
195	7.6772	0.0002	0.0006	0.0011	0.0002
200	7.8740	0.0002	0.0006	0.0011	0.0002
205	8.0709	0.0002	0.0006	0.0011	0.0002

For bearings less than 25 mm. in inside diameter, a press fit of 0.0004 in. should be obtained by selected assembly.
Shaft diameters should be measured with a micrometer.

ALLOWANCES IN HOUSINGS

Outside Diameter of Bearing				Fit in Housing	
Nominal		Tolerances			
Mm.	In.	Plus	Minus	Tight	Loose
30	1.1811	0.0000	0.0005	0.0000	0.0015
32	1.2598	0.0000	0.0005	0.0000	0.0015
35	1.3780	0.0000	0.0005	0.0000	0.0015
37	1.4567	0.0000	0.0005	0.0000	0.0015
40	1.5748	0.0000	0.0005	0.0000	0.0015
42	1.6535	0.0000	0.0005	0.0000	0.0015
47	1.8504	0.0000	0.0005	0.0000	0.0015
52	2.0472	0.0000	0.0008	0.0000	0.0018
62	2.4409	0.0000	0.0008	0.0000	0.0018
72	2.8346	0.0000	0.0008	0.0000	0.0018
80	3.1496	0.0000	0.0008	0.0000	0.0018
85	3.3465	0.0000	0.0008	0.0000	0.0018
90	3.5433	0.0000	0.0008	0.0000	0.0018
100	3.9370	0.0000	0.0008	0.0000	0.0018
110	4.3307	0.0000	0.0008	0.0000	0.0018
120	4.7244	0.0000	0.0008	0.0000	0.0018
125	4.9213	0.0000	0.0008	0.0000	0.0018
130	5.1181	0.0000	0.0008	0.0000	0.0023
140	5.5118	0.0000	0.0008	0.0000	0.0023
150	5.9055	0.0000	0.0012	0.0000	0.0027
160	6.2992	0.0000	0.0012	0.0000	0.0027
170	6.6929	0.0000	0.0012	0.0000	0.0027
180	7.0866	0.0000	0.0012	0.0000	0.0027
190	7.4803	0.0000	0.0012	0.0000	0.0027
200	7.8740	0.0000	0.0012	0.0000	0.0027
210	8.2677	0.0000	0.0012	0.0000	0.0027
215	8.4646	0.0000	0.0012	0.0000	0.0027
220	8.6614	0.0000	0.0012	0.0000	0.0027
225	8.8583	0.0000	0.0012	0.0000	0.0027
230	9.0551	0.0000	0.0012	0.0000	0.0027
240	9.4488	0.0000	0.0012	0.0000	0.0027
250	9.8425	0.0000	0.0012	0.0000	0.0027
260	10.2362	0.0000	0.0012	0.0000	0.0027
265	10.4331	0.0000	0.0012	0.0000	0.0032
270	10.6299	0.0000	0.0012	0.0000	0.0032
280	11.0236	0.0000	0.0012	0.0000	0.0032
290	11.4173	0.0000	0.0012	0.0000	0.0032
300	11.8110	0.0000	0.0012	0.0000	0.0032
310	12.2047	0.0000	0.0012	0.0000	0.0032
320	12.5984	0.0000	0.0012	0.0000	0.0032
330	12.9921	0.0000	0.0012	0.0000	0.0032
340	13.3858	0.0000	0.0012	0.0000	0.0032
350	13.7795	0.0000	0.0012	0.0000	0.0032
360	14.1732	0.0000	0.0012	0.0000	0.0032
370	14.5669	0.0000	0.0012	0.0000	0.0032
380	14.9606	0.0000	0.0012	0.0000	0.0032
390	15.3543	0.0000	0.0012	0.0000	0.0032
400	15.7480	0.0000	0.0012		

Housing bores should be measured with a plug gage.

THE DISCUSSION

Mr. Crane:—I think that it would be of considerable advantage if the information given in these tables was in a little different form. Any one who has had experience with machine work knows that shaft tolerances of plus 0.0005 and minus 0.0000 in. are out of the question; for instance, an axle company would not furnish axles to dimensions based on these tolerances.

W. R. Strickland:—I might mention that these fits are based on grinding fits. The reason the shaft and housing sizes were given as they are was so that manufacturers who want to work more closely than this can do so and as a matter of fact, when they grind to the dimensions given, 75 per cent of the sizes will be within a couple ten-thousandths of the figures given.

Earle Buckingham:—The outside diameters of the bearings, for example, a 200 millimeter size, are given a tolerance of 0.0012 (and this is a ground fit), while just half a thousandth is given on the shaft. A half thousandth could be held on the smaller diameters, but I fail to see how the larger diameters could be measured and checked accurately in production to that half thousandth fit without extremely accurate measuring instruments. A micrometer would never do it.

Mr. Crane:—The tables, as I understand them, are simply a reproduction of the already accepted standard

tolerances on ball bearings. The Division feels that it is desirable that certain limits of fit should be used in fitting bearings on shafts; that they should never be more than a certain amount tight nor a certain amount loose to be a passable fit. My object in suggesting the change is to leave to the manufacturer of the shafts the matter of how he shall obtain that fit. He would set his own limits on the diameter of the shaft or housing to meet what he considers correct fits.

F. W. GURNEY:—What the Division has tried to do is to give some tolerances and allowances which can be met, although as a matter of actual practice perhaps they would not be met in the majority of cases. The only way to get the fits that are desired in the great majority of cases is by selective fitting, but in some instances where such fits cannot be afforded, a fit all the way from 0.0002 in. loose to 0.0009 in. tight can be endured. In cases where such practice will not do, the only way to get along is to make selective fits, unless bearings specially selected to give narrower limits than the adopted S.A.E. Standards are requested.

(4) *Annular Ball Bearings—Separable (Open) Type*

The Ball and Roller Bearings Division recommends that the present S.A.E. Standard for Separable (Open) Type Annular Ball Bearings, page C32, S.A.E. HANDBOOK, Vol. I. (new edition), be revised as follows:

Change the heading in the column "Width of individual rings" to read "Overall width" and add tolerances of plus or minus 0.002 in. to be placed on the "Overall width."

Add the footnote referring to overall widths, to read "The nominal width of individual rings shall be the same as for the overall widths in the above table but shall have tolerances of plus or minus 0.001 in."

(5) *Annular Ball Bearings—Wide Type*

The Ball and Roller Bearings Division recommends that the present S.A.E. Standard for Extra Wide Type Annular Ball Bearings, page C31; S.A.E. HANDBOOK, Vol. I (new edition), be amplified as follows to make it more complete:

Change the Sub-title "Extra Wide Type" to read "Wide Type" and add the note, "The bore and outside diameters for wide type annular ball bearings shall be the same as for the corresponding size annular ball bearings in the light, medium and heavy series."

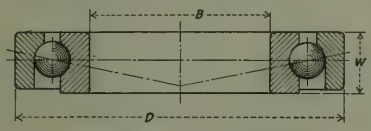
Also add the footnote referring to the title, to read "Normally these bearings are a double-row type of construction."

(6) *Angular Contact Ball Bearings*

The present S.A.E. Standard for Angular Contact Ball Bearings of the light, medium and heavy series is as follows:

Ball bearings of the angular contact type are identical in size and boundary dimensions with S.A.E. Standard annular ball bearings of the light, medium and heavy series as printed on page C33, S.A.E. HANDBOOK, Vol. I (new edition).

Toward completing the standard for angular contact bearings, consensus of opinion of the Ball and Roller Bearings Division members is that the bore, outside diameter and eccentricity tolerances specified for light, medium



ANGULAR CONTACT TYPE BEARING

and heavy series annular ball bearings be adhered to for the angular contact type, and that the tolerances for the overall widths be specified as in the table, with the footnote reading, "The width tolerances for the individual rings shall be the same as those of the corresponding sizes of annular ball bearings of the light, medium and heavy series." It is also recommended that the angular contact type bearings table be published as separate and

ANGULAR CONTACT BALL BEARINGS—LIGHT SERIES

Bearing Number	Bore			Outside Diameter			Overall Width[2]			Minimum Corner Radius		Eccentricity Tolerances, In.	
	Mm.	In.	Inch Tolerances Plus 0.0002 Minus	Mm.	In.	Inch Tolerances Plus 0.0000 Minus	Mm.	In.	Inch Tolerances Plus or Minus	Mm.	In.	Inner Race	Outer Race
200	10	0.39370	0.0004	30	1.18110	0.0005	9	0.35433	0.003	1	0.04	0.0006	0.0012
201	12	0.47244	0.0004	32	1.25984	0.0005	10	0.39370	0.003	1	0.04	0.0006	0.0012
202	15	0.59055	0.0004	35	1.37795	0.0005	11	0.43307	0.003	1	0.04	0.0006	0.0012
203	17	0.66929	0.0004	40	1.57481	0.0005	12	0.47244	0.003	1	0.04	0.0006	0.0012
204	20	0.78740	0.0004	47	1.85040	0.0005	14	0.55118	0.003	1	0.04	0.0006	0.0012
205	25	0.98425	0.0004	52	2.04725	0.0008	15	0.59055	0.003	1	0.04	0.0008	0.0012
206	30	1.18110	0.0004	62	2.44095	0.0008	16	0.62992	0.003	1	0.04	0.0008	0.0012
207	35	1.37795	0.0004	72	2.83465	0.0008	17	0.66929	0.003	1	0.04	0.0008	0.0012
208	40	1.57481	0.0004	80	3.14962	0.0008	18	0.70866	0.003	2	0.08	0.0008	0.0012
209	45	1.77166	0.0004	85	3.34647	0.0008	19	0.74803	0.003	2	0.08	0.0010	0.0016
210	50	1.96851	0.0004	90	3.54332	0.0008	20	0.78740	0.003	2	0.08	0.0010	0.0016
211	55	2.16536	0.0004	100	3.93702	0.0008	21	0.82677	0.003	2	0.08	0.0010	0.0016
212	60	2.36221	0.0005	110	4.33072	0.0008	22	0.86614	0.003	2	0.08	0.0010	0.0016
213	65	2.55906	0.0005	120	4.72443	0.0008	23	0.90551	0.005	2	0.08	0.0010	0.0016
214	70	2.75591	0.0005	125	4.92128	0.0008	24	0.94488	0.005	2	0.08	0.0010	0.0016
215	75	2.95277	0.0005	130	5.11813	0.0008	25	0.98425	0.005	2	0.08	0.0010	0.0016
216	80	3.14962	0.0005	140	5.51183	0.0008	26	1.02362	0.005	3	0.12	0.0012	0.0018
217	85	3.34647	0.0006	150	5.90554	0.0012	28	1.10236	0.010	3	0.12	0.0012	0.0018
218	90	3.54332	0.0006	160	6.29924	0.0012	30	1.18110	0.010	3	0.12	0.0012	0.0018
219	95	3.74017	0.0006	170	6.69294	0.0012	32	1.25984	0.010	3	0.12	0.0012	0.0018
220	100	3.93702	0.0006	180	7.08664	0.0012	34	1.33858	0.010	3	0.12	0.0012	0.0018
221	105	4.13387	0.0006	190	7.48035	0.0012	36	1.41732	0.010	3	0.12	0.0012	0.0018
222	110	4.33072	0.0006	200	7.87405	0.0012	38	1.49607	0.010	3	0.12	0.0012	0.0018

[2]Width tolerances of individual rings shall be the same as the width tolerances of corresponding sizes of Annular Ball Bearings of the Light, Medium and Heavy Series.

ANGULAR CONTACT BALL BEARINGS—MEDIUM SERIES

Bearing Number	Bore			Outside Diameter			Overall Width[3]			Minimum Corner Radius		Eccentricity Tolerances, In.	
	Mm.	In.	Inch Tolerances Plus 0.0002 Minus	Mm.	In.	Inch Tolerances Plus 0.0000 Minus	Mm.	In.	Inch Tolerances Plus or Minus	Mm.	In.	Inner Race	Outer Race
300	10	0.39370	0.0004	35	1.37795	0.0005	11	0.43307	0.003	1	0.04	0.0006	0.0012
301	12	0.47244	0.0004	37	1.45669	0.0005	12	0.47244	0.003	1	0.04	0.0006	0.0012
302	15	0.59055	0.0004	42	1.65355	0.0005	13	0.51181	0.003	1	0.04	0.0006	0.0012
303	17	0.66929	0.0004	47	1.85040	0.0005	14	0.55118	0.003	1	0.04	0.0006	0.0012
304	20	0.78740	0.0004	52	2.04725	0.0008	15	0.59055	0.003	1	0.04	0.0006	0.0012
305	25	0.98425	0.0004	62	2.44095	0.0008	17	0.66929	0.003	1	0.04	0.0008	0.0012
306	30	1.18110	0.0004	72	2.83465	0.0008	19	0.74803	0.003	2	0.08	0.0008	0.0012
307	35	1.37795	0.0004	80	3.14962	0.0008	21	0.82677	0.003	2	0.08	0.0008	0.0012
308	40	1.57481	0.0004	90	3.54332	0.0008	23	0.90551	0.003	2	0.08	0.0008	0.0012
309	45	1.77166	0.0004	100	3.93702	0.0008	25	0.98425	0.003	2	0.08	0.0010	0.0016
310	50	1.96851	0.0004	110	4.33072	0.0008	27	1.06299	0.003	2	0.08	0.0010	0.0016
311	55	2.16536	0.0004	120	4.72443	0.0008	29	1.14173	0.003	2	0.08	0.0010	0.0016
312	60	2.36221	0.0005	130	5.11813	0.0008	31	1.22047	0.003	2	0.08	0.0010	0.0016
313	65	2.55906	0.0005	140	5.51183	0.0008	33	1.29921	0.005	3	0.12	0.0010	0.0016
314	70	2.75591	0.0005	150	5.90554	0.0012	35	1.37795	0.005	3	0.12	0.0010	0.0016
315	75	2.95277	0.0005	160	6.29924	0.0012	37	1.45669	0.005	3	0.12	0.0010	0.0016
316	80	3.14962	0.0005	170	6.69294	0.0012	39	1.53544	0.005	3	0.12	0.0012	0.0018
317	85	3.34647	0.0006	180	7.08664	0.0012	41	1.61418	0.010	3	0.12	0.0012	0.0018
318	90	3.54332	0.0006	190	7.48035	0.0012	43	1.69292	0.010	3	0.12	0.0012	0.0018
319	95	3.74017	0.0006	200	7.87405	0.0012	45	1.77166	0.010	3	0.12	0.0012	0.0018
320	100	3.93702	0.0006	215	8.46460	0.0012	47	1.85040	0.010	3	0.12	0.0012	0.0018
321	105	4.13387	0.0006	225	8.85830	0.0012	49	1.92914	0.010	3	0.12	0.0012	0.0018
322	110	4.33072	0.0006	240	9.44886	0.0012	50	1.96851	0.010	3	0.12	0.0012	0.0018

[3]Width tolerances of individual rings shall be the same as the width tolerances of corresponding sizes of Annular Ball Bearings of the Light, Medium and Heavy Series.

ANGULAR CONTACT BALL BEARINGS—HEAVY SERIES

Bearing Number	Bore			Outside Diameter			Overall Width[4]			Minimum Corner Radius		Eccentricity Tolerances, In.	
	Mm.	In.	Inch Tolerances Plus 0.0002 Minus	Mm.	In.	Inch Tolerances Plus 0.0000 Minus	Mm.	In.	Inch Tolerances Plus or Minus	Mm.	In.	Inner Race	Outer Race
403	17	0.66929	0 0004	62	2.44095	0 0008	17	0.66929	0 003	1	0.04	0.0006	0.0012
404	20	0.78740	0.0004	72	2.83465	0 0008	19	0.74803	0.003	2	0.08	0.0006	0.0012
405	25	0.98425	0 0004	80	3.14962	0 0008	21	0.82677	0.003	2	0.08	0.0008	0.0012
406	30	1.18110	0.0004	90	3 54332	0.0008	23	0.90551	0 003	2	0.08	0.0008	0.0012
407	35	1.37795	0.0004	100	3.93702	0 0008	25	0.98425	0 003	2	0 08	0.0008	0.0012
408	40	1.57481	0.0004	110	4.33072	0 0008	27	1.06299	0 003	2	0 08	0.0008	0.0012
409	45	1.77166	0.0004	120	4 72443	0 0008	29	1.14173	0 003	2	0.08	0.0010	0.0016
410	50	1.96851	0.0004	130	5.11813	0 0008	31	1.22047	0 003	2	0.08	0 0010	0.0016
411	55	2.16536	0.0004	140	5.51183	0 0008	33	1.29921	0 003	3	0.12	0 0010	0 0016
412	60	2.36221	0 0005	150	5 90554	0.0012	35	1.37795	0.003	3	0.12	0 0010	0 0016
413	65	2 55906	0.0005	160	6 29924	0 0012	37	1.45669	0.005	3	0.12	0.0010	0.0016
414	70	2.75591	0.0005	180	7.08664	0.0012	42	1.65355	0.005	3	0.12	0.0010	0 0016
415	75	2.95277	0.0005	190	7 48035	0.0012	45	1.77166	0.005	3	0.12	0.0010	0.0016
416	80	3.14962	0.0005	200	7.87405	0.0012	48	1.88977	0.005	3	0.12	0.0012	0.0018
417	85	3.34647	0.0006	210	8.26775	0.0012	52	2.04725	0.010	3	0.12	0.0012	0.0018
418	90	3.54332	0.0006	225	8.85830	0 0012	54	2.12599	0.010	3	0.12	0.0012	0.0018
419	95	3.74017	0 0006	250	9 84256	0.0012	55	2.16536	0.010	3	0.12	0.0012	0.0018
420	100	3.93702	0.0006	265	10.43311	0.0012	60	2.36221	0.010	3	0.12	0.0012	0 0018

[4]Width tolerances of individual rings shall be the same as the width tolerances of corresponding sizes of Annular Ball Bearings of the Light, Medium and Heavy Series.

complete standards as in the accompanying tables toward facilitating their use.

The present standard extended to conform to these recommendations is given in the tables on this and the preceding page.

Electric Transportation Division Report

(7) *Electric Vehicle Storage Battery Jars*

The recommendation of the Electric Transportation Division that the present S.A.E. Standard for Electric Vehicle Storage Battery Jars, page B39, S.A.E. Handbook, Vol. 1 (new edition), be revised was amended and approved as given below.

The action of the Division in eliminating the low-rib type of jar is on account of the fact that a more efficient storage battery can be designed with the high-rib type.

[5]This is in accordance with the specification of the Hard Rubber Division of the War Service Commission issued Aug. 28, 1918.

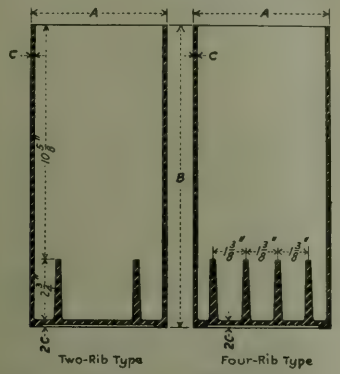
Electric Passenger Vehicle Jars. Hard rubber jars shall have a nominal tensile strength of 3000 lb. per sq. in. with a nominal elongation of 5 per cent; a tensile strength of 3600 lb. per sq. in. with an elongation of not less than 3 per cent; an elongation of not less than 6 per cent with a tensile strength of not less than 2700 lb. per sq. in.; and for intermediate values of the tensile strength and the elongation the numerical product of the tensile strength in pounds per square inch and the elongation in percentage shall not be less than 15,000.[5]

The nominal wall thickness shall be ⅛ in. with tolerances of plus zero and minus 1/64 in.; all types shall have a width of 6⅛ in., an overall height of 13⅝ in., a rib height of 2¾ in. and a height from the top of the rib to the top of the jar of 10⅝ in. The number of sizes shall be limited to 15, with the following outside lengths: 2 5/16, 2½, 2 13/16, 3, 3⅛, 3 5/16, 3½, 3 11/16, 3 13/16, 4, 4¼, 4½, 4 13/16, 5 and 5 5/16 in.

The tolerances for the length, width and height shall be plus or minus 1/32 in.

Jars shall have 2 or 4 ribs; when 4 ribs are used they shall be 1⅜ in. between centers.

Electric Commercial Vehicle Jars. Hard rubber jars shall have a nominal tensile strength of 5000 lb. per sq. in. with an elongation of 6 per cent; a tensile strength



ELECTRIC VEHICLE STORAGE BATTERY JARS

Class	Overall Width (A)	Overall Height (B)	Wall Thickness (C)	Overall Length		Nominal Inside Length
				Nominal	Tolerances	
1	6²⁹/₃₂ +1/32 −3/64	13³¹/₃₂	3/32 +0 −1/64	2³/₃₂ 2⁹/₃₂ 2⁷/₈ 3³/₃₂ 3⁹/₃₂ 4³/₃₂ 4⁹/₃₂ 4⁷/₈ 5³/₃₂ 5⁹/₃₂	+1/32 −3/64	1⁹/₃₂ 2¹/₄ 2⁹/₃₂ 2⁹/₄ 3¹/₄ 3⁹/₄ 4 4⁹/₃₂ 4⁹/₄ 5¹/₄
2	6¹/₄ ±3/64	13³/₄	3/32 +1/128 −1/64	5⁷/₈ 6¹/₈ 6¹/₄ 6⁵/₈ 6⁷/₈ 7¹/₈ 7⁵/₈ 7⁷/₈	±3/64	5¹/₂ 5⁵/₈ 5⁷/₈ 6¹/₄ 6¹/₂ 6⁵/₈ 7 7¹/₈ 7¹/₄
3	6¹/₄ +3/64 −1/32	13³/₄	3/32 +1/128 −1/64	8¹/₈ 8³/₈ 8⁵/₈ 8⁷/₈ 9³/₈ 9⁵/₈ 10 10³/₈	+3/64 −1/32	7⁹/₄ 8¹/₄ 8⁵/₈ 8⁷/₈ 9 9¹/₄ 9⁵/₈ 10
4	6¹/₄ ±1/32	13³/₄	3/32 +1/128 −1/64	10⁵/₈ 11¹/₈ 11³/₄ 11⁷/₈ 12⁵/₈	±1/16	10¹/₄ 10⁵/₈ 10⁷/₈ 11¹/₂ 12¹/₄

All dimensions in inches.

of not less than 4000 lb. per sq. in. with an elongation of not less than 7½ per cent; an elongation of not less than 5 per cent with a tensile strength of not less than 6000 lb. per sq. in.; and for intermediate values of the tensile strength and the elongation the product of the tensile strength in pounds per square inch and the elongation in percentage shall be not less than 30,000.*

Jars shall have 2 or 4 ribs; when 4 ribs are used they shall be 1⅜ in. between centers.

*This is in accordance with War Department Specification No. 223-1-38 issued May 1, 1919 for Storage Batteries for Industrial Tractors and Trucks.

This recommendation also applies to industrial truck and tractor storage battery jars.

THE DISCUSSION

W. E. HOLLAND:—We have found that the rubber manufacturers are divided on the use of the dimension shown for two-rib jars. The Division specified 3½ in. but some of the rubber manufacturers are using 3¼ in. We have not had time since discovering this to meet with the rubber manufacturers and decide on a compromise. It would mean a great expense to some of them to change all their jar mandrels from 3¼ to 3½ in. or vice versa. I therefore recommend that this report be amended to eliminate the 3½-in. dimension on two-rib jars, until we can determine on it at a later date.

BRUCE FORD:—I think Mr. Holland's point is very well taken, inasmuch as this difference exists in the mandrels of the different rubber manufacturers. I think it makes no difference whether that dimension is 3¼ or 3½ in. We could eliminate the 3½-in. dimension from the drawing and change the paragraph referring to the rib spacing to read as follows:

> Jars shall have two or four ribs. When four ribs are used, the spacing shall be 1⅜ in. between centers.

It is important to have the rib spacing match up properly in the four-rib jar, because feet are used, on the plates, but in the two-rib jar feet are not used.

R. W. WOODWARD:—I am not particularly familiar with the testing of hard rubber or materials such as battery jars are composed of, but it seemed to me, in reading these specifications, that there might be some difficulty in meeting them, particularly as to the tensile strength and elongation. We know that a test-specimen means considerable difference in results obtained. It is possible that such a condition exists in testing rubber of this type. I would like to inquire whether the Division has considered that, and whether it is advisable to specifiy the type of specimens to be used in getting these results.

MR. FORD:—I think the best answer to that is that these specifications are already in existence and have been used by the rubber manufacturers for many years. It would be rather difficult to get any other specification that they would understand and that would be workable. This is practical because it is in operation and has worked satisfactorily.

E. L. CLARK:—I think that the tensile strength and elongation specifications for the jars for commercial vehicles are the same as the Navy Standard. There is a reference note stating that they are the same as the War Department specification of May 1, 1919.

MR. FORD:—There is a slight difference in the wording, but the compound is substantially the same. The matter of tolerances is a little different and I think that the specification as it now stands is better because it is based on the experience resulting from other specifications which were found more or less wanting in some respects.

ELECTRICAL EQUIPMENT DIVISION REPORT

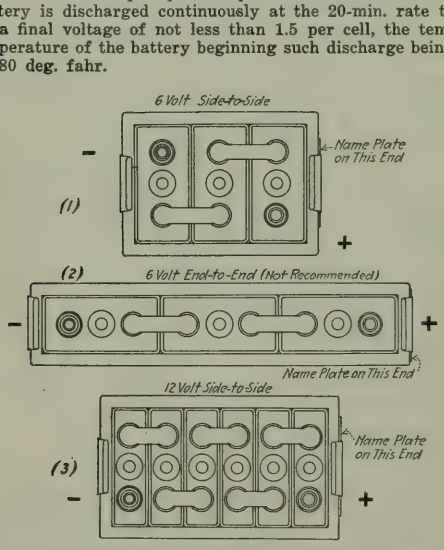
(8) *Storage Batteries*

The Electrical Equipment Division appointed a Subdivision on Storage Batteries in January, 1919, to cooperate with the Bureau of Standards and the Motor Transport Corps in the formulation of specifications for starting and lighting storage batteries for military automobile and motor truck service for the use of the Government, and to revise the present storage battery standards. Several joint meetings, which members of the S.A.E. Subdivision on Storage Batteries, members of

the A.I.E.E. Sub-Committee on Storage Batteries and representatives of the Bureau of Standards, the Navy Department, the Motor Transport Corps, the Automotive Electric Association, and storage battery manufacturers attended, were held. These resulted in the formulation of a specification which was printed in the December 1920 issue of THE JOURNAL.

On the completion of this work the Subdivision gave careful consideration to revising the present S.A.E. Standards for storage battery terminal posts, posts for small cells, storage battery compartments, dimensions of lead batteries for lighting and for combined lighting and starting service, and rating of lead batteries for lighting and for combined lighting and starting service on gasoline automobiles, pages B23 and B24, S.A.E. HANDBOOK, Vol. I (new edition). It was considered advisable to combine these standards under one heading entitled "Lead-Acid Storage Batteries." The complete recommendation was approved as follows:

Ratings—Batteries for combined starting and lighting service shall have two ratings. The first rating shall indicate the lighting ability and shall be the capacity in ampere-hours when the battery is discharged continuously at the 5-hr. rate to a final voltage of not less than 1.7 per cell, the temperature of the battery beginning such discharge being 80 deg. fahr. The second rating shall indicate the starting ability and shall be the capacity in ampere-hours when the battery is discharged continuously at the 20-min. rate to a final voltage of not less than 1.5 per cell, the temperature of the battery beginning such discharge being 80 deg. fahr.



LOCATION OF STORAGE BATTERY TERMINAL POSTS, HANDLES AND NAME PLATES

The location and polarity of the terminal posts and the position of the handles and the name plates shall be as shown in the accompanying illustration.

Terminal Posts—When taper posts are used for terminals of lead-acid storage batteries, the dimensions in inches shall be

Small diameter of the negative post	5/8
Small diameter of the positive post	11/16
Taper per foot	1-1/3
Minimum length of taper	11/16

When straight terminal posts are used, the diameter of both the positive and negative posts shall be 13/16 in. and the minimum clear length of the post shall be 13/16 in.

These dimensions refer to batteries for lighting service as well as for combined starting and lighting service.

LEAD-ACID STORAGE BATTERY SIZES AND CAPACITIES

No.	No. of Cells	Minimum Capacity Amp-Hr.		Maximum Overall Dimensions, In.[7]			Fig. No.
		5-hr. rate	20-min. rate	Length	Width	Height	
1	3	60	31	9¾	7½	9⅞	1
2	3	72	37	11⅝	7½	9⅞	1
3	3	84	43	12⅝	7½	9⅞	1
4	3	84	43	20⅝	4¾	9⅞	2[8]
5	3	96	50	13¾	7½	9⅞	1
6	3	96	43	15⅝	7½	9⅞	1
7	3	95	43	20⅝	5⅝	9⅞	2[8]
8	6	36	19	13¼	7½	9⅞	1
9	6	48	25	15⅝	7½	9⅞	3

Dimensions in inches.

[7]The overall length of batteries for starting and lighting service measured from end to end of case includes handles, but not hold-down devices. The space occupied by the handles and the hold-down devices shall be only in the direction of the length of the battery, not in the direction of its width. Terminals and connections shall not extend above the handles; the latter shall be the highest point.

[8]Not recommended.

Compartments—Compartments for starting and lighting batteries shall be of metal not less than 18 United States plate gage (0.050 in.) in thickness, supported entirely by the chassis.

Battery compartments shall be 8 in. wide and 10⅛ in. high in order to give a ¼-in. clearance all around the battery. End-to-end assembly of jars is not recommended on account of the inherent weakness of this type of construction.

The battery shall rest on two wooden strips each 2 in. wide by ¼-in. thick, running lengthwise of the compartment. These shall be positively spaced with the edges flush with the sides of the battery. Spacers shall be provided to give a ¼-in. space at each side of the battery and a 1½-in. space at each end outside of the hold-down devices.

The compartment shall be drained and ventilated.

The hold-down devices should be attached at the level of the top of the battery, not to the top of the handles.

The principal differences between this report and the standards are as follows:

The report is specifically limited to lead-acid storage batteries in order that the specification will not be applied to Edison storage batteries.

The S.A.E. Recommended Practice for Posts for Small Cells, page B23, S.A.E. HANDBOOK, Vol. I (new edition), is omitted as the battery sizes proposed for adoption do not require the use of small terminal posts.

The compartment height of 10 in. specified in the present S.A.E. Standard for Storage Battery Compartments, page B24, S.A.E. HANDBOOK, Vol. I (new edition), is changed to 10⅛ in.

The present S.A.E. Standard for dimensions of Lead Storage Batteries for Starting and Lighting Service, page B23, S.A.E. HANDBOOK, Vol. I (new edition), is revised to specify a list of the sizes and capacities based on present practice which is considered comprehensive enough for practically all commercial requirements.

The present S.A.E. Standard for Ratings of Lead Storage Batteries for Starting and Lighting Service is revised to conform with acceptable commercial practice.

THE DISCUSSION

R. H. COMBS:—I fail to understand why it is necessary or even advisable to have tapered posts of different sizes

on the positive and negative ends of the battery when the same provision for safety has not been made on the straight post. If it is necessary with a tapered post, and we say it is, then it is equally necessary, if not more so, on a straight post, as it will give more security than will be apparent on a tapered post.

MR. FORD:—In standardizing we are trying to eliminate unnecessary types and not to initiate new types. The straight post was never made with a differential in size of positive and negative. The only kind of a straight post that was ever used was the same diameter for the positive and the negative. If we were to introduce straight posts having different diameters for positive and negative, we would be introducing something that is not in use.

(9) *Fuses and Fuse Clips*

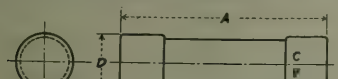
The present S.A.E. Standard printed on page B32, S.A.E. HANDBOOK, Vol. I (new edition), was originally adopted in January, 1914, and revised somewhat in 1918. With the development of electrical apparatus on automobiles the practice has become more established as regards the use of fuse sizes and capacities and as to the requirements of fuse tests. The Division corresponded with the manufacturers of fuses in order to obtain definite information as to best current practice. These data have been used in preparing the following recommendation which more definitely limits the number of fuse sizes and their capacities and includes what is considered ample testing requirements. The recommendation of the Electrical Equipment Division that the present standard be revised to read as follows was approved:

Fuses for use on circuits of 25 volts or less and 30 amp. or less shall be of the closed type and constructed so that inspection will show whether or not they have been melted.

Marking.—The voltage (V) and the current capacity (C) shall be plainly marked on one of the ferrules of each fuse. Fuses of the same dimensions as the National Electric Code shall be marked according to the requirements of that code.

Construction.—Fuses shall be constructed so that with the surrounding atmosphere at a temperature of 75 deg. fahr. (24 deg. cent.) they will carry indefinitely a current 10 per cent greater than that at which they are rated. With a current 50 per cent greater than the rating and at a room temperature of 75 deg. fahr. (24 deg. cent.) the fuses starting cold shall melt within 1 min.

The temperature of the exterior of the fuses shall rise not more than 125 deg. fahr. (70 deg. cent.) above that of the surrounding air when the fuse is carrying the current for which it is rated.



FUSE MARKINGS AND DIMENSIONS

Capacity, Amp.	Length, In. (A)	Ferrule Diameter, In. (B)
5	1 1/4	1/4
10	1 1/4	1/4
15	1 1/4	1/4
20	1 1/4	1/4
30	1 1/2	13/32

Clips.—Fuse clips shall be made so that fuses cannot slip out accidentally and fastened to a base that cannot turn. Clips shall be designed and protected so that they cannot be drawn together enough to take a permanent set interfering with the insertion of the fuse or so that they can be sprung apart far enough to give them a permanent set sufficient to prevent holding the fuse tightly. Clips shall be nickel-plated.

Ferrules.—Fuse ferrules shall be nickel-plated.

Tests.—Fuses shall be tested in both the vertical and horizontal positions.

(10) *Spark-Plug Tests*

It has been evident for some time that some definite guide for the testing of spark-plugs will be of value to both spark-plug manufacturers and users. Last year the Division cooperated with the Motor Transport Corps in the establishment of a Government specification for the testing of spark-plugs and from this work developed the following recommendation for commercial use. The recommendation is not intended as an iron bound specification but rather as a definite guide towards the ready elimination of freak or inferior plugs. The recommendation was prepared by a Subdivision and tried out by making actual tests and in consultation with the spark-plug manufacturers. The recommendation of the Electrical Equipment Division that the specification printed below be adopted for S.A.E. Recommended Practice was approved.

A sufficient number of sample spark-plugs drawn at random from stock are to be furnished to equip at least two of the engines under consideration

The spark-plugs submitted for test must conform in all important dimensions to the engine builder's drawings

Preignition and leakage tests are to be made in the following manner. An engine of the type for which the plugs are intended shall be equipped with a set of the spark-plugs to be tested. The spark-plug gaps shall be carefully adjusted with a suitable thickness gage to the desired dimension and these gaps shall not be disturbed throughout the tests. The engine shall then be coupled to a suitable dynamometer and the circulating water maintained at a temperature of not less than 40 deg. fahr. or more than 60 deg. fahr. The engine shall then be started up and as rapidly as possible brought to the speed corresponding to the maximum torque, the throttle and the spark adjusted for this condition, and the circulating water temperature brought up to a temperature of not less than 190 deg. fahr. nor more than 210 deg. fahr. as rapidly as possible and this temperature maintained for the remainder of the run. Torque and speed readings shall then be taken at 30-sec. intervals for a period of 15 min. Appreciable loss of torque or speed, missing or backfiring which can be attributed to the spark-plugs, will be considered grounds for rejecting the spark-plugs under test, provided the engine is of proved design and has previously demonstrated its ability to run steadily under these conditions. During this run, tests for gas leakage shall be made by covering all joints of the spark-plugs with oil and inspecting for leaks.

Following this 15-min. run at the speed corresponding to maximum torque, the engine shall be brought up to the speed corresponding to maximum horsepower and be held at this speed for not less than 5 min. Observations similar to those mentioned above are to be made during this run.

Spark-plugs shall also be subjected to road tests to determine how well they will function under normal service conditions.

Spark-plugs which have successfully passed the above tests will be considered satisfactory for use insofar as the following points are concerned

(1) Breakage owing to sudden temperature changes

(2) Liability to cause preignition
(3) Leakage
(4) Power performance
(5) Permanence of gap

The following procedure for determining the relative susceptibility of the spark-plugs under test to fouling is intended to serve merely as a guide in making such tests, since general engine influences and more particularly lubrication and carburetion conditions, varying as they do in different makes of engine, prohibit the setting of one strictly standard method applicable to all engines.

The engine equipped with the spark-plugs under test shall be run on the dynamometer with the circulating water at not less than 40 deg. fahr. nor more than 60 deg. fahr. The inlet manifold shall be kept at as low a temperature as practicable, all heating means being disconnected so far as possible. The engine shall be run with no load and a wide-open throttle, the speed being held down to between 1000 and 1500 r.p.m. by causing the carbureter to feed an abnormally rich mixture. The engine shall be run in this manner for 3 min., following which the carbureter adjustment shall be restored to standard condition and the load applied to hold the engine at a speed of about 1200 r.p.m. It is assumed that the torque which is to be expected of the engine under test at this speed, has been previously determined. At the end of 2 min. running after applying the load as above explained, the percentage of standard torque which the engine is capable of developing will be considered as a figure of merit for the spark-plugs under test. For instance, if at the end of 2 min. operation under load following the "choked" run, the engine is capable of pulling its standard torque, the spark-plugs shall be considered 100 per cent satisfactory in this regard. If, however, the engine pulls but one-half its regular torque, the figure of merit will be 50. These tests should be repeated a sufficient number of times to insure a consistent average result.

(11) *Magneto Dimensions*

Since the adoption of the present standard printed on page B14, S.A.E. HANDBOOK, Vol. I (new edition), a small type motorcycle magneto has been developed on which there has been some variation of the threaded and taper shaft-end. It was requested by the Motorcycle Division that this variation be eliminated and a Subdivision which was accordingly assigned to prepare a report has recommended that for small motorcycle and isolated electric lighting plant magnetos the same size taper be used as given in the present recommended practice for larger type motorcycle magnetos printed in the S.A.E. HANDBOOK. The recommendation of the Electrical Equipment Division that the present S.A.E. Recommended Practice be extended to include the above was approved.

(12) *Starting-Motor Pinions*

The recommendation of the Electrical Equipment Division that the present S.A.E. Recommended Practice for Starting Motor Pinions, page B18, S.A.E. HANDBOOK, Vol. I (new edition), be revised to specify the clearance between the pinion and the flywheel on the pitch line was approved to read as follows:

> Flywheel starting motors shall be equipped with an 8-10 pitch, 11-tooth, 20-deg. pressure angle pinion. The clearance on the pitch line between the pinion and the flywheel shall be from 0.015 to 0.025 in.

THE DISCUSSION

GLENN MUFFLY:—What is meant by the pitch-line clearance? Frequently an engineer says that he reduces the pitch diameter of a gear, thereby giving a pitch-line clearance; that is technically impossible.

EARLE BUCKINGHAM:—The pitch-line of a gear does not exist until it is brought into contact with another gear. The pitch-line is the point where the line of action crosses the common center-line of two gears, so there could not be a pitch-line clearance.

MR. CRANE:—It will make the report clear if it is changed to read that the clearance on the pitch-line between the pinion and the flywheel shall be 0.015 to 0.025 in.

(13) *Brushes*

The Electrical Equipment Division was requested to ascertain whether a standard could not be established for starting motor and lighting generator brushes. After careful consideration of data pertaining to brush sizes and the possibility of the advantage of such a standard to the manufacturers of brushes by reducing the number of sizes of plates from which they are made, it was considered practical to establish a standard only for the steps by which brush dimensions should vary. The standard brush dimensions of the Electric Power Club as published August, 1920, were considered but as the sizes covered in general by this standard are larger than those used in automotive electrical equipment and as the increases between sizes are too large, the recommendation of the Electrical Equipment Division that the following standard be adopted for S.A.E. Recommended Practice was approved. This recommendation permits of obtaining brushes with small variation in contact surface on the commutator, and having but one set of tolerances for all sizes, these tolerances applying to the brushes before they are plated. It was not considered advisable to attempt standardization of chamfering or methods of fastening brush leads.

> All dimensions for brushes used in starting motors and lighting generators shall vary by even increments of 1/16 in. and the maximum tolerances from nominal size shall be plus 0.000 minus 0.010 in. for width and thickness and plus 0.000 minus 0.031 (1/32) in. for length.

(14) *Addition of Electrical Appliances to Gasoline Automobiles*

The present S.A.E. Standard which was adopted several years ago reads as follows:

> Before any electrical appliance is added to a gasoline car, after it is sent out from the car manufacturer's plant, a description of the said appliance should be submitted to the car manufacturer as to suitability for and the best method of application to the car.

It is the intention of the Society to make the S.A.E. HANDBOOK of the greatest value to the Society members and users of the standards. Such standards as the above are gradually being eliminated. If manufacturers and users attempted to abide by such a standard it would cause almost endless confusion and entail considerable expense without accomplishing any results. Such procedure as required by the standard is contrary to commonly accepted practice in placing many electrical appliances and accessories on motor cars. The recommendation of the Electrical Equipment Division that this standard be cancelled was approved.

ENGINE DIVISION REPORT

(15) *Mufflers*

When the suggestion for standardization of muffler mountings and connections was brought to the attention of the Engine Division, a Subdivision was formed

consisting of engine and muffler manufacturers. Investigation indicated that muffler capacity is too closely associated with engine design to warrant standardization in this direction. Opinions and practices as to methods of mounting seem to vary considerably, although muffler manufacturers seem to favor the use of bands as now recommended. The possibility of standardizing the exhaust and tail-pipe connection was considered but due to wide variation in types, practice and connections, it was thought better not to attempt such standardization until there is a sufficient demand for it.

In order to provide some definite guide for practice, the following, based on the Subdivision report, was recommended by the Engine Division and approved for adoption as S.A.E. Recommended Practice.

> Mufflers shall vary in diameter and length by even inches and shall be supported by bands extending around the circumference.

(16) *Flywheel Housings*

In connection with the present S.A.E. Standard Flywheel Housings, pages A1, A2 and A3, S.A.E. HANDBOOK, Vol. I (new edition) it was proposed that the maximum clearance dimensions for the crankshaft flange bolt be established to facilitate interchanging clutches and to provide for uniform design in assembled jobs. The original intention was to standardize the bolt-circle diameters and head clearances, but it was believed from study of present and possible future practice in connection with shaft bearing diameters, oil slingers and other controlling features, that there will be of necessity considerable variation.

It was therefore thought best to provide for a standard maximum clearance as a guide to clutch and engine manufacturers and the recommendation of the Engine Division to add the following to the present S.A.E. Recommended Practice was approved.

> The clearance space for crankshaft flange bolts shall be 6⅛ in. maximum diameter and at least ⅝ in. deep.

(17) *Fan-Belts and Pulleys*

The present standard which was adopted by the Society August, 1915, includes only four nominal belt widths, namely ¾, 1, 1¼ and 1½ in. The development of engines and cooling systems of larger capacity for truck and tractor work has required greater fan belt power. The request of the Truck Division to extend the number of belt widths has been acted upon by the Engine Division, whose recommendation that 1¾ and 2-in. belt widths and corresponding pulley widths be added to the present standard was approved. The complete revised standard as now recommended is as follows:

FAN-BELT AND PULLEY WIDTHS

Nominal Belt Width, In. ±1/32	Nominal Pulley Width, In. ±0.005
¾	0.875
1	1.125
1¼	1.375
1½	1.685
1¾	2.000
2	2.250

The Division is at present working on the subject of V-belts which are used to a considerable extent. It includes leather, rubber and canvas types and is apparently more involved by reason of the different angles of the V best suited to the operation of each and to differences in design. It is anticipated that a recommendation will be had for the next meeting of the Standards Committee.

(18) *Carbureter Intake*

With the advent of air-cleaners for use on tractors, it was felt by members of the Tractor Division that standardization should be provided especially for the air-cleaner outlet and the carbureter air inlet. The matter was assigned to the Engine Division which, after considerable study of the possibilities, decided that the only dimension on air-cleaners which should be standardized for the present at least is the outside diameter of the tubing leading from the air-cleaner outlet to the carbureter air intake. The Engine Division recommendation that the following be adopted as S.A.E. Recommended Practice was approved.

> The nominal diameter of the carbureter air intake shall be the inside diameter, which shall vary in even quarter inches (from ¾ to 4 in. diameters) so as to take standard tubing sizes as listed in the present S.A.E. Standard for Flexible Metal Tubing, page C54, S.A.E. HANDBOOK, Vol. I (new edition). This also applies to the outlet of carbureter air-cleaners, heaters and similar devices wherever tubing is used.

(19) *Carbureter Air Heaters*

The present S.A.E. Recommended Practice for Carbureter Air-Heaters was adopted by the Society in August, 1915, but with the more recent developments in apparatus to obtain efficient fueling of engine, this specification has become obsolete. The recommendation of the Engine Division that the present recommended practice for carbureter air heaters be cancelled was approved.

MISCELLANEOUS DIVISION REPORT

(20) *American Standard Taper Pipe Threads*

The American Standard Taper Pipe Threads, commonly known as the American Briggs Standard, which has been endorsed by the A.S.M.E. and a manufacturers' committee representing fittings, pipe and gage manufacturers, has been in use very generally in the United States.

The report of the National Screw Thread Commission, which was authorized by act of Congress in July, 1918, for the purpose of ascertaining and establishing standards for screw threads, includes the sizes and dimensions for taper pipe threads which correspond to those in the American taper pipe standard sizes.

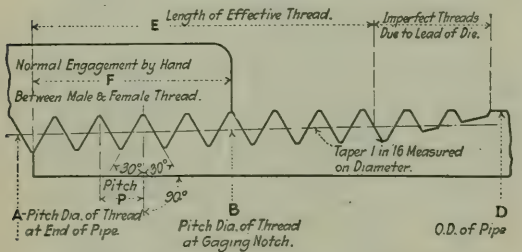
In 1915 a movement was fostered by the American Gas Institute and the A.S.M.E. for the international standardization of taper pipe threads, but little was accomplished until in 1919 the Committee of the A.S.M.E. held a public hearing for the consideration of international pipe threads. Mr. Edwin H. Ehrman and Mr. Jerome J. Aull were appointed by the Council of the Society of Automotive Engineers to attend this hearing as a special committee and reported as follows:

> The Manual of American Standard Pipe Threads, dated October, 1919, was prepared by representative committees of valve and fitting, pipe and pipe thread gage manufacturers. It covers the entire subject of pipe sizes, threads, gages, tolerances, etc. in inch and metric measurements in very complete and accurate detail. While involving no change in present American pipe thread practice it clarifies and amplifies the subject in all its phases, particularly in the usage of gages and their tolerances.

Following the above hearing the Society was requested

to give official endorsement to the American standard and to authorize an American representative in Europe to use such endorsement in propagating the standard among European manufacturers and technical organizations prior to a contemplated international conference.

Although such a standard for taper pipe threads has not been considered by the Standards Committee of the Society it was deemed advisable to take official action on this matter in view of the proposed program for international standardization and the Society's connection with the project. The Council therefore assigned this subject to the Miscellaneous Division, which at its meeting on September 24, 1920, regularly voted to endorse the N.S.T.C. taper pipe thread specification providing that it does not differ in any essential features from that of the Committee of the A.S.M.E. pipe and fitting manufacturers. Although it was felt that this standard should be officially approved by the American Engineering Standards Committee it is thought desirable that the Society of Automotive Engineers take definite action if possible at this time by endorsing or adopting the report for standard. Only the diagram and table for the American Taper Pipe Thread Standard are given below as approved for adoption.



At present taper threads are used in only a few of the S.A.E Standards, namely, Flared Tube Unions, Ells and Tees, Fuel Vacuum Tanks, Pipe Flanges and Oil and Grease Cup Threads.

Diameter of Taper Thread The pitch diameters of the taper thread are determined by formulas based on the outside diameter of pipe and the pitch of thread. These are as follows:

$$A = D - (0.050D + 1.1)\ P$$

$$B = A + 0.0625F.$$

where A = Pitch diameter of thread at end of pipe
B = Pitch diameter of thread at gaging notch
D = Outside diameter of pipe
F = Normal engagement by hand between external and internal threads
P = Pitch of thread

NOTE.—The above formulas are not expressed in the same terms as the formula originally established by Mr. Robert Briggs, because they are used to determine pitch diameters, whereas the Briggs formula determined the outside diameter of the thread. However, both forms give identical results.

The outside diameter of pipe is given in column *D* of the Table of dimensions. These diameters should be very closely adhered to by pipe manufacturers.

Profile The angle between the sides of the thread is 60 deg. when measured in the axial plane, and the thread is perpendicular to the axis of the pipe, for both taper and straight threads. The crest and root are truncated an amount equal to 0.033*P*. The depth of the thread, therefore, is 0.80*P*.

NOTE.—While Mr. Briggs originally advocated a slightly *rounded* crest and root, the thread as applied in the manufacture of gages and thread tools has always been slightly *flattened* at the crest and root. The crests on commercially manufactured male and female threads appear slightly rounded

AMERICAN STANDARD TAPER PIPE THREAD

DIMENSIONS OF AMERICAN STANDARD TAPER PIPE THREAD

Nominal Pipe Size		A		B		D		E		F		Depth of Thread		Number of Threads	
In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	Per In.	Per 254 Mm.
1/8	3	0.36351	9.233	0.37476	9.519	0.405	10.287	0.2638	6.700	0.180	4.572	0.02963	0.753	27	270
1/4	6	0.47739	12.126	0.48989	12.443	0.540	13.716	0.4018	10.206	0.200	5.080	0.04444	1.129	18	180
3/8	10	0.61201	15.545	0.62701	15.926	0.675	17.145	0.4078	10.358	0.240	6.096	0.04444	1.129	18	180
1/2	13	0.75843	19.264	0.77843	19.772	0.840	21.336	0.5337	13.556	0.320	8.128	0.05714	1.451	14	140
3/4	19	0.96768	24.579	0.98886	25.117	1.050	26.670	0.5457	13.861	0.339	8.611	0.05714	1.451	14	140
1	25	1.21363	30.826	1.23863	31.461	1.315	33.401	0.6828	17.343	0.400	10.160	0.06956	1.767	11½	115
1¼	32	1.55713	39.551	1.58338	40.218	1.660	42.164	0.7068	17.953	0.420	10.668	0.06956	1.767	11½	115
1½	38	1.79609	45.621	1.82234	46.287	1.900	48.260	0.7235	18.377	0.420	10.668	0.06956	1.767	11½	115
2	50	2.26902	57.633	2.29627	58.325	2.375	60.325	0.7565	19.215	0.436	11.074	0.06956	1.767	11½	115
2½	64	2.71953	69.076	2.76216	70.159	2.875	73.025	1.1375	28.892	0.682	17.323	0.10000	2.540	8	80
3	76	3.34063	84.852	3.38850	86.068	3.500	88.900	1.2000	30.480	0.766	19.456	0.10000	2.540	8	80
3½	90	3.83750	97.473	3.88881	98.776	4.000	101.600	1.2500	31.750	0.821	20.853	0.10000	2.540	8	80
4	100	4.33438	110.093	4.38713	111.433	4.500	114.300	1.3000	33.020	0.844	21.438	0.10000	2.540	8	80
4½	113	4.83125	122.714	4.88594	124.103	5.000	127.000	1.3500	34.290	0.875	22.225	0.10000	2.540	8	80
5	125	5.39073	136.925	5.44929	138.412	5.563	141.300	1.4063	35.720	0.937	23.800	0.10000	2.540	8	80
6	150	6.44609	163.731	6.50597	165.252	6.625	168.275	1.5125	38.417	0.958	24.333	0.10000	2.540	8	80
7	175	7.43984	188.972	7.50234	190.560	7.625	193.675	1.6125	40.957	1.000	25.400	0.10000	2.540	8	80
8	200	8.43359	214.214	8.50003	215.901	8.625	219.075	1.7125	43.497	1.063	27.000	0.10000	2.540	8	80
9	225	9.42734	239.455	9.49797	241.249	9.625	244.475	1.8125	46.037	1.130	28.702	0.10000	2.540	8	80
10	250	10.54531	267.851	10.62094	269.772	10.750	273.050	1.9250	48.895	1.210	30.734	0.10000	2.540	8	80
11	275	11.53906	293.093	11.61938	295.133	11.750	298.450	2.0250	51.435	1.285	32.639	0.10000	2.540	8	80
12	300	12.53281	318.334	12.61781	320.493	12.750	323.851	2.1250	53.975	1.360	34.544	0.10000	2.540	8	80
14 O.D.	350	13.77500	349.886	13.87262	352.365	14.000	355.601	2.2500	57.150	1.562	39.675	0.10000	2.540	8	80
15 O.D.	375	14.76875	375.127	14.87419	377.805	15.000	381.001	2.3500	59.690	1.687	42.850	0.10000	2.540	8	80
16 O.D.	400	15.76250	400.368	15.87575	403.245	16.000	406.401	2.4500	62.230	1.812	46.025	0.10000	2.540	8	80
17 O.D.	425	16.75625	425.609	16.87500	428.626	17.000	431.801	2.5500	64.770	1.900	48.260	0.10000	2.540	8	80
18 O.D.	450	17.75000	450.851	17.87500	454.026	18.000	457.201	2.6500	67.310	2.000	50.800	0.10000	2.540	8	80
20 O.D.	500	19.73750	501.333	19.87031	504.707	20.000	508.001	2.8500	72.390	2.125	53.975	0.10000	2.540	8	80
22 O.D.	550	21.72500	551.816	21.86562	555.388	22.000	558.801	3.0500	77.470	2.250	57.150	0.10000	2.540	8	80
24 O.D.	600	23.71250	602.299	23.86094	606.069	24.000	609.601	3.2500	82.550	2.375	60.325	0.10000	2.540	8	80
26 O.D.	650	25.70000	652.781	25.85625	656.750	26.000	660.401	3.4500	87.630	2.500	63.500	0.10000	2.540	8	80
28 O.D.	700	27.68750	703.264	27.85156	707.431	28.000	711.201	3.6500	92.710	2.625	66.675	0.10000	2.540	8	80
30 O.D.	750	29.67500	753.746	29.84687	758.112	30.000	762.001	3.8500	97.790	2.750	69.850	0.10000	2.540	8	80

The dimensions of American Pipe Threads are expressed in "inches" to 0.00001 in., and in "millimeters" to 0.001 mm. While this is a greater degree of accuracy than is ordinarily used, the dimensions are so expressed to eliminate errors which might result from less accurate dimensions.

The relation between the inch and the meter used in calculating the dimensions in these tables is that established by law in the United States and on record in the Bureau of Standards, Department of Commerce and Labor, Washington. This is 1 meter = 39.37 in. exactly. The metric equivalent of the inch resulting from this determination is 25.40005 mm.

when examined with a microscope, but for all practical purposes, when examined by eye, they are sharp. The roots of commercially manufactured threads are practically sharp when cut with new tools and slightly rounded when cut with worn tools.

Pitch The pitch of the thread is expressed in terms of the number of threads in 1 in. or the number of threads in 254 mm. (254 mm. equals 10 in.).

Length of Thread The length of the taper external or male thread is determined by a formula based on the outside diameter of pipe and the pitch of the thread. This is as follows:

$$E = (0.80D + 6.8)\ P$$

where E = Length of effective thread
G = Outside diameter of pipe
P = Pitch of thread

NOTE.—The formula is not expressed in the same terms as the one originally established by Mr. Briggs, since it determines directly the length of *effective* thread which includes two threads slightly imperfect on the crest, whereas the Briggs formula determined the length of *perfect* thread, not including the two threads imperfect on the crest. However, both forms of the formula give identical results.

Engagement between Taper Male and Female Threads The normal length of engagement between taper male and female threads when screwed together by hand is shown in Column *F* of the Table. This length is controlled by the construction and use of the gages.

THE DISCUSSION

CHAIRMAN BACHMAN:—The American Standard for taper pipe threads which is in general practice was approved by the American Engineering Standards Committee as the American Standard in December, 1919. It is now within the province of the Society to accept it and to recognize it as an S. A. E. Standard for our work. Of course, the range of pipe and pipe-thread sizes used in some of the fields of automotive work is limited; in others it is more extensive.

MR. AULL:—I question whether the name "American Standard" is correct. I believe I am right when I say that the National Screw Thread Commission calls it a National Standard.

CHAIRMAN BACHMAN:—There has been some division of opinion on that point. My understanding of the procedure of the American Engineering Standards Committee, of which I am a member, is that standards that have been approved by that body take the name "American Standards."

MR. AULL:—Personally, I am in favor of "American Standard" because "National Standard" conveys nothing to me, while "American Standard" does.

MR. BUCKINGHAM:—American Standard is the name by which it is known.

(21) *Oil and Grease Cup-Threads*

The present recommended practice for oil and grease-cup threads which was adopted by the Society in August, 1920, includes straight thread sizes for ¼-36 and 5/16-32 threads only. The common standard fine thread pitch for ¼ in. diameter is 32, but the corresponding thread adopted by the Society, principally for aeronautic purposes, was 36 threads. The previous recommendation for oil-cups of this size was adopted in order to if possible conform to the existing S.A.E. fine thread. This size has been quite generally criticized as being contrary to practically universal practice, such criticisms coming principally from the largest manufacturers of this article. The Miscellaneous Division has therefore reconsidered its previous action and recommended the addition of a No. 10-32 size and the revision of the ¼-36 to ¼-32 in the belief that such a standard will conform to general practice and at the same time be limited to only those sizes which will remain in permanent use. No change is contemplated in the present standard for the pipe thread sizes of grease and oil-cups and the above recommendation has been approved.

MOTORCYCLE DIVISION REPORT

(22) *Spokes and Nipples*

The present S.A.E. Recommended Practice for Motorcycle Spokes and Nipples, page F4, S.A.E. HANDBOOK, Vol. I (new edition), specifies a steel having a chemical composition slightly different from that of S.A.E. Steel No. 1045. The two compositions are given for comparison.

	Present Specified Composition	S.A.E. Steel No. 1045
Carbon	0.40 to 0.55 per cent	0.40 to 0.50 per cent
Manganese, min.	0.50 per cent	0.50 to 0.80 per cent
Phosphorus, max.	0.05 per cent	0.045 per cent
Sulphur, max.	0.05 per cent	0.05 per cent

In order to have the specification conform to the standard steel it was referred to the motorcycle manufacturers, who advised that their specifications either call for S.A.E. Steel No. 1045 or can be changed to do so, and that spokes made to this analysis will be entirely satisfactory. The Division's recommendation that the present recommended practice be revised to specify S.A.E. Steel No. 1045 has been approved.

(23) *Motorcycle Wheels and Rims*

The present S.A.E. Recommended Practice for Motorcycle Wheels and Rims, page G9, S.A.E. HANDBOOK, Vol. I (new edition), specifies a steel composition for rims which is very nearly the same as Steel No. 1010 as indicated below:

	Present Specified Composition	S.A.E. Steel No. 1010
Carbon	0.10 to 0.15 per cent	0.05 to 0.15 per cent
Manganese	0.40 to 0.60 per cent	0.30 to 0.60 per cent
Phosphorus, max.	0.05 per cent	0.045 per cent
Sulphur, max.	0.05 per cent	0.05 per cent

S.A.E. steel No. 1010 will be as satisfactory as those made of the non-standard steel at present specified in the HANDBOOK and as it is desired to eliminate the non-standard steel specification, the Division's recommendation that the present S.A.E. Recommended Practice for Motorcycle Wheels and Rims be revised to specify S.A.E. Steel No. 1010 was approved.

(24) *Motorcycle Controls*

The Motorcycle Division has recommended that the present S.A.E. Recommended Practices for spark and throttle controls, clutch and brake pedals and gearshift, which were formulated as military motorcycle standards, be withdrawn, as they are not applicable to commercial practice owing to the different constructions used in present-day machines necessitating different locations and movements of controls. The cancellation of these recommended practices was approved.

The recommended practices are printed on page J8, S.A.E. HANDBOOK, Vol. I (new edition).

NON-FERROUS METALS DIVISION REPORT

The existing standards of the Society were adopted from seven to nine years ago with very slight revisions since then. Development in the production and use of non-ferrous metals and alloys has reached a point where the existing standard specifications are very inadequate. The Non-Ferrous Metals Division has therefore prepared

the following report for non-ferrous alloys which have been grouped into five general classes. These proposed specifications are considered ample for general automotive purposes and have been arranged so far as possible so as to give information relative to the general use of each alloy, its chemical composition and in most cases, physical properties. The numbering system has been arranged with sufficient flexibility to insert added specifications as conditions may require. The compositions have been carefully developed with regard to what is considered best metallurgical practice as well as specifications used by the Government and recommended by such other organizations as the American Society for Testing Materials. It is expected that the recommended specifications will become as important an S.A.E. Standard as the present standard steels. The recommendation of the Non-Ferrous Metals Division that these specifications be adopted as S.A.E. Standard was approved. They will supersede the non-ferrous specifications now in the S.A.E. HANDBOOK with the exception of the present aluminum specifications Nos. 30, 31 and 32 which will be retained.

(25) *Non-Ferrous Metal Specifications*

WHITE BEARING METALS

Specification No. 11, Babbitt.

Composition in percentage:

Tin	86.00 to 89.00
Copper	5.00 to 6.50
Antimony	6.00 to 7.50
Lead, max.	0.35
Iron, max.	0.08
Arsenic, max.	0.10
Bismuth, max.	0.08
Zinc	None
Aluminum	None

General Information

This is a rather hard babbitt which may be used for lining connecting-rod and shaft bearings which are subjected to heavy pressures; its "wiping" tendency is very slight. It is also suitable for die castings.

Specification No. 12, Babbitt.

Composition in percentage:

Antimony	9.50 to 11.50
Copper	2.25 to 3.75
Lead	24.00 to 26.00
Iron, max.	0.08
Bismuth, max.	0.08
Zinc	None
Aluminum	None
Tin	Remainder

General Information

This is a relatively cheap babbitt and is intended for bearings subjected to moderate pressures. It is also suitable for die castings.

Specification No. 10, Babbitt.

Composition in percentage:

Tin	90.00 to 92.00
Copper	4.00 to 5.00
Antimony	4.00 to 5.00
Lead, max.	0.35
Iron, max.	0.08
Arsenic, max.	0.10
Bismuth, max.	0.08
Zinc	None
Aluminum	None

This analysis applies to the metal in the ingot form. When finished bearings are purchased a maximum of 0.6 per cent lead is permissible in scraped samples provided a lead-tin solder has been used in bonding the bronze and the babbitt.

General Information

This babbitt is very fluid and may be used for bronze-backed bearings, particularly for thin linings such as are used in aircraft engines. It is also suitable for die castings.

Specification No. 13, Babbitt.

Composition in percentage:

Tin	4.50 to 5.50
Antimony	9.25 to 10.75
Copper, max.	0.50
Lead	84.00 to 86.00
Arsenic, max.	0.20
Zinc	None
Aluminum	None

General Information

This is a cheap babbitt and serves successfully where the bearings are large and the service light. It should not be used as a substitute for a babbitt with a high tin content. It is also suitable for die castings.

ALUMINUM ALLOYS

Specification No. 30.

Composition in percentage:

Aluminum, min.	90.00
Copper	7.00 to 8.50
Zinc, max.	0.20
Silicon, Iron, Zinc, Manganese and Tin, max.	1.70
Other Impurities	None

General Information

The tensile strength of test-specimens about ½ in. diameter of this alloy cast in sand and tested without machining off the skin should be about 18,000 to 20,000 lb. per sq. in. and the elongation 1 to 2 per cent in 2 in.

This is a light alloy having a specific gravity of about 2.83 and is used more extensively in the automotive industry than all other light casting alloys combined. A shrinkage of 0.156 (5/32) in. per ft. should be allowed in pattern designs. This alloy is used for crankcases, oil-pans, steering-wheel spiders, differential carriers, transmission cases, camshaft housings, hub-caps and similar parts.

Specification No. 31.

Composition in percentage:

Aluminum, min.	81.00
Copper	2.25 to 3.25
Zinc	12.50 to 14.50
Silicon, Iron, Manganese and Tin, max.	1.70
Other Impurities	None

General Information

The tensile strength of test-specimens about ½-in. diameter of this alloy cast in sand and tested without machining off the skin should be about 25,000 to 30,000 lb. per sq. in. with an elongation of more than 1 per cent in 2 in.

The specific gravity is about 3.0 and a shrinkage of 0.156 (5/32) in. per ft. should be allowed in pattern designs.

This alloy is used extensively in England for such parts as crankcases, oil-pans, steering-wheel spiders and transmission cases.

Specification No. 32.

Composition in percentage:

Aluminum, min.	85.50
Copper	11.00 to 13.50
Zinc, max.	0.20
Silicon, Iron, Zinc, Manganese and Tin, max.	1.70
Other Impurities	None

General Information

The tensile strength of test-specimens about ½-in. diameter of this alloy cast in sand and tested without machining off the skin

should be about 19,000 to 23,000 lb. per sq. in. and the elongation will be practically nothing.

The specific gravity of this alloy is about 2.95 and a shrinkage of 0.156 (5/32) in. per ft. should be allowed in pattern designs. This alloy is used for manifolds, pumps, carbureters, cylinders and other parts which should be free from leaks and where the brittleness of the alloy is not objectionable.

Specification No. 33.

Composition in percentage:

Aluminum	88.00 to 92.00
Copper	6.00 to 8.00
Zinc, max.	2.50
Iron, max.	1.50
Silicon, Manganese and Tin, max.	0.75
Other Impurities	None

General Information

The tensile strength of test-specimens about ½-in. diameter of this alloy cast in sand and tested without machining off the skin should be about 19,000 to 21,000 lb. per sq. in. with an elongation of 1 to 2 per cent in 2 in.

This is a light alloy having a specific gravity of 2.83 to 2.86 and is used extensively in the automotive industry. A shrinkage of 0.156 (5/32) in. per ft. should be allowed in pattern designs.

This alloy is similar to Specification No. 30 and is used for crankcases, oil-pans, steering-wheel spiders, differential carriers, transmission cases, camshaft housings, hub-caps and similar parts.

CAST BRASS ALLOYS

Specification No. 40 (Old No. 27), Red Brass.

Composition in percentage:

Copper	83.00 to 86.00
Tin	4.50 to 5.50
Lead	4.50 to 5.50
Zinc	4.50 to 5.50
Iron, max.	0.35
Antimony, max.	0.25
Aluminum	None

General Information

Good castings made of this alloy should give the following minima in physical characteristics:

Ultimate strength, lb. per sq. in.	27,000
Yield point, lb. per sq. in.	12,000
Elongation in 2 in. or proportionate gage length, per cent	16

This is a free-cutting brass with good casting and finishing properties.

Specification No. 43 (Old No. 29), Manganese Bronze.

Composition in percentage:

Copper	53.00 to 62.00
Zinc	38.00 to 47.00
Lead, max.	0.15

This metal may be hardened by the addition of small amounts of tin, iron, manganese, aluminum or combination of these metals. The most importance should be placed on the following minima in physical requirements:

Ultimate strength, lb. per. sq. in.	60,000
Yield point, lb. per sq. in.	30,000
Elongation in 2 in. or proportionate gage length, per cent	15

General Information

This alloy is intended for use in castings where strength and toughness are required. It is equivalent to the copper-zinc alloys commercially known as Cast Manganese Bronze or its equivalents, such as Cast Tobin Bronze and Cast Naval Bronze.

Specification No. 41 (Old No. 28), Yellow Brass.

Composition in percentage:

Copper	62.00 to 65.00
Lead	2.00 to 4.00
Zinc	31.00 to 36.00
Tin, max.	1.00
Iron, max.	0.50
Aluminum	None
Other Impurities	0.25

General Information

Good castings made of this alloy should give the following minima in physical characteristics:

Ultimate strength, lb. per sq. in.	25,000
Yield point, lb. per sq. in.	12,000
Elongation in 2 in. or proportionate gage length, per cent	20

This alloy is intended for use in commercial castings where cheapness and good machining properties are the main considerations.

Specification No. 42, White Nickel Brass.

Composition in percentage:

Copper	55.00 to 64.00
Nickel, min.	18.00
Iron, max.	0.35
Aluminum	None
Other Impurities	0.25
Zinc	Remainder

General Information

Good castings made of this alloy should give the following minima in physical characteristics:

Ultimate strength, lb. per sq. in.	30,000
Elongation in 2 in. or proportionate gage length, per cent	20

This brass is intended for use for trimmings or other parts requiring a metallic-white finish. The higher the nickel content, the more permanent will be the color.

BRONZE ALLOYS

Bearings or gears made of bronze alloys should be used only against hardened steel.

Specification No. 62 (Old No. 43), Hard Cast Bronze

Composition in percentage:

Copper	86.00 to 89.00
Tin	9.00 to 11.00
Lead, max.	0.20
Iron, max.	0.06
Zinc	1.00 to 3.00

General Information

Good castings made of this bronze should give the following minima in physical characteristics:

Ultimate strength, lb. per sq. in.	30,000
Yield point, lb. per sq. in.	15,000
Elongation in 2 in. or proportionate gage length, per cent	14

This alloy is suitable wherever a strong general utility bronze is required. It may be used for severe working conditions where heavy pressures obtain, as in gears and bearings.

Specification No. 63, Leaded Gun Metal.

Composition in percentage:

Copper	86.00 to 89.00
Tin	9.00 to 11.00
Phosphorus, max.	0.25
Zinc and Other Impurities max.	0.50
Lead	1.00 to 2.50

General Information

Good castings made of this alloy should give the following minima in physical characteristics:

Ultimate strength, lb. per sq. in.	30,000
Yield point, lb. per. sq. in.	12,000
Elongation in 2 in. or proportionate gage length, per cent	10

Combining strength with fair machining qualities, this general utility bronze is especially good for bushings subjected to heavy loads and severe working conditions.

Specification No. 65, Phosphor Gear Bronze.

Composition in percentage:

Copper	88.00 to 90.00
Tin	10.00 to 12.00
Phosphorus	0.10 to 0.30
Lead, Zinc and Other Impurities, max.	0.50

General Information

Good castings made of this alloy should give the following minima in physical characteristics:

Ultimate strength, lb. per sq. in.	35,000
Yield point, lb. per sq. in.	20,000
Elongation in 2 in. or proportionate gage length, per cent.	10

This is a very hard bronze and may be used for gears and worm wheels where the requirements are severe.

Specification No. 64 (Old No. 26), Phosphor Bronze.

Composition in percentage:

Copper	78.50 to 81.50
Tin	9.00 to 11.00
Lead	9.00 to 11.00
Phosphorus	0.05 to 0.25
Zinc, max.	0.75
Other Impurities, max.	0.25

General Information

Good castings made of this alloy should give the following minima in physical characteristics:

Ultimate strength, lb. per sq. in.	25,000
Yield point, lb. per sq. in.	12,000
Elongation in 2 in. or proportionate gage length, per cent.	8

This metal is an excellent composition for use where anti-friction qualities are desired, standing up exceedingly well under heavy loads and severe usage.

Specification No. 66, Bronze Backing for Lined Bearings.

Composition in percentage:

Copper	83.00 to 86.00
Tin	4.50 to 6.00
Lead	8.00 to 10.00
Zinc, max.	2.00
Impurities, max.	0.25

General Information

Good castings made of this alloy should give the following minima in physical characteristics:

Ultimate strength, lb. per sq. in.	25,000
Yield point, lb. per sq. in.	12,000
Elongation in 2 in. or proportionate gage length, per cent.	8

This composition is recommended as an inexpensive but suitable alloy for bronze-backed bearings.

Specification No. 67, Semi-Plastic Bronze.

Composition in percentage:

Copper	75.50 to 78.50
Tin	7.25 to 8.75
Lead	13.50 to 16.50
Zinc, max.	0.50
Phosphorus, max.	0.25
Iron, max.	0.25
Antimony, max.	0.50
Aluminum	None
Impurities, max.	0.75

General Information

Good castings made of this alloy should give the following minima in physical characteristics:

Ultimate strength, lb. per sq. in.	20,000
Elongation in 2 in. or proportionate gage length, per cent.	10

This metal is intended for use where a soft bronze with good anti-friction qualities is desired.

Specification No. 68, Cast Aluminum Bronze.

Composition in percentage:

Copper	85.00 to 87.00
Aluminum	7.00 to 9.00
Iron	2.50 to 4.50
Tin (none desired), max.	0.50
Other Impurities, max.	0.25

General Information

Good castings made of this alloy should give the following minima in mechanical properties:

Ultimate strength, lb. per sq. in.	65,000
Yield point, lb. per sq. in.	20,000
Elongation in 2 in. or proportionate gage length, per cent.	20

This is a non-corrodible alloy of great strength with a hardness equal to that of manganese bronze and good bearing qualities. It is suitable for use in worm wheels, gears and similar parts.

Specification No. 69, Wrought Aluminum Bronze.

Composition in percentage:

Copper	85.00 to 87.00
Aluminum	7.00 to 9.00
Iron	2.50 to 4.50
Tin (none desired), max.	0.50
Other Impurities	0.25

General Information

Wrought shapes, rods and bars of this alloy, the composition of which is identical with Specification No. 68, combine unusual strength with good bearing and anti-corrosive qualities.

Wrought bars made of this alloy, when annealed or hot-rolled, should give the following minima in physical characteristics:

Diameter or Thickness, In.		Ultimate Strength, Lb. per Sq. In.	Yield Point, Lb. Per Sq. In.	Elongation in 2 In. or Proportionate Gage Length, Per Cent
Over	To and Including			
0	1/2	80,000	40,000	30
1/2	1	75,000	37,500	28
1		72,000	35,000	25

Commercial Brass Sheet

Specification No. 70.

This alloy may be used for general purposes for which sheet brass is suitable.

Composition in percentage:

Copper	64.50 to 67.50
Lead, max.	0.35
Iron, max.	0.06
Other Impurities, max.	0.10
Zinc	Remainder

Physical Requirements

Temper and Anneal.—The temper of sheet brass shall be designated as follows:

	Reduction, B. & S. Gage Nos.
Quarter Hard	1
Half Hard	2
Hard	4
Extra Hard	6
Spring	8

The annealed sheet shall be designated as follows:

Light Anneal.
Drawing Anneal.
Soft Drawing Anneal.

Mechanical Requirements

The average of tension tests of two samples of sheet thinner than 0.080 in. shall conform to the following minimum requirements:

Temper	Minimum Ult. Strength, Lb. Per Sq. In.	Minimum Elongation in 2 In., Per Cent
Quarter Hard	45,000	27.5
Half Hard	52,500	15.0
Hard	67,500	5.0
Extra Hard	80,000	2.0
Spring	87,500	1.0
Light Anneal	45,000	32.0
Drawing Annea	42,000	38.0
Soft Drawing Annea	40,000	42.0

In very thin strips, on account of the difficulties in testing, the elongation may be considerably less than the figures given above.

THICKNESS TOLERANCES

B. & S. Gage No.		Decimal		Up to 5 in. Wide, Incl.	Over 5 in. to 8 in. Wide, Incl.	Over 8 in. to 11 in. Wide, Incl.	Over 11 in. to 14 in. Wide, Incl.
From	To	From	To				
0000	0	0.4600	0.3249	0.0044	0.0048	0.0051	0.0055
1	4	0.2893	0.2043	0.0039	0.0043	0.0046	0.0050
5	8	0.1819	0.1285	0.0034	0.0038	0.0041	0.0045
9	14	0.1144	0.0641	0.0029	0.0033	0.0036	0.0040
15	18	0.0571	0.0403	0.0025	0.0029	0.0033	0.0037
19	24	0.0359	0.0201	0.0020	0.0024	0.0028	0.0032
25	28	0.0179	0.0126	0.0016	0.0020	0.0024	0.0028
29	32	0.0113	0.0079	0.0013	0.0017	0.0020	0.0024
33	35	0.0071	0.0056	0.0010	0.0014	0.0017	0.0022
36	38	0.0055	0.0040	0.0008	0.0012	0.0015	0.0019

All dimensions in inches. All tolerances plus or minus.

The average Brinell hardness of 10 samples of sheet 0.080 in. or over in thickness shall be within the following limits:

Quarter Hard	75–95
Half Hard	95–115
Hard	130–150
Extra Hard	150–170
Spring	160–180
Light Anneal	65–75
Drawing Anneal	55–65
Soft Drawing Anneal	47–55

These should be considered as general specifications. Since high brass is used for many purposes where the requirements of the operations used are too particular to be specified by any of the ordinary physical tests, it is frequently advisable to submit samples or drawings to the manufacturer and secure an adjustment of anneal or temper to suit the actual operations to which the material is to be submitted.

Copper Sheet

Specification No. 71.

Composition in percentage:

Copper, min.	99.50

Mechanical Requirements

ULTIMATE STRENGTH AND ELONGATION

Temper	Ultimate Strength, Min., Lb. Per Sq. In.	Elongation in 2 In., Min., Per Cent
Hard-Rolled	30,000 32,000	25 18

Bend Test.—Test-pieces cut either way of the grain must stand cold-bending flat on themselves without cracking.

THICKNESS TOLERANCES

B. & S. Gage No.		Decimal		Up to 5 in. Wide, Incl.	Over 5 in. to 8 in. Wide, Incl.	Over 8 in. to 11 in. Wide, Incl.	Over 11 in. to 14 in. Wide, Incl.
From	To	From	To				
0000	0	0.4600	0.3249	0.0044	0.0048	0.0051	0.0055
1	4	0.2893	0.2043	0.0039	0.0043	0.0046	0.0050
5	8	0.1819	0.1285	0.0034	0.0038	0.0041	0.0045
9	14	0.1144	0.0641	0.0029	0.0033	0.0036	0.0040
15	18	0.0571	0.0403	0.0025	0.0029	0.0033	0.0037
19	24	0.0359	0.0201	0.0020	0.0024	0.0028	0.0032
25	28	0.0179	0.0126	0.0016	0.0020	0.0024	0.0028
29	32	0.0113	0.0079	0.0013	0.0017	0.0020	0.0024
33	35	0.0071	0.0050	0.0010	0.0014	0.0017	0.0022
36	38	0.0045	0.0031	0.0008	0.0012	0.0015	0.0019

All dimensions in inches. All tolerances plus or minus.

Free-Cutting Brass Rod

Specification No. 72 (Old No. 40).

This metal is intended for all purposes for which free-cutting, commercial brass rod is used.

Composition in percentage:

Copper	60.00 to 63.00
Lead	2.25 to 3.25
Iron, max.	0.15
Other Impurities, max.	0.25
Zinc	Remainder

When several bars or rods are analyzed they should meet this specification. If only one rod or bar is sampled, the following limits will be acceptable:

Copper, per cent	59.40 to 63.60
Lead, per cent	1.80 to 3.90

Mechanical Requirements

Bend Test.—Rods or bars shall bend cold without fracture through an angle of 120 deg. around a pin the radius of which is equal to the diameter or thickness of the rod or bar.

Dimensions and Tolerances.—The diameter of round sections shall not vary from that specified by more than the tolerances given in the following table:

DIMENSIONS AND TOLERANCES

Diameter, In.		Tolerances, In. Plus or Minus
Over	To and Including	
	½	0.0015
½	1	0.0020
1	2½	0.0025
2½		0.0030

In the case of other than round sections the distance between parallel faces shall be permitted to vary, in their respective sizes, double the amount of the above tolerances.

Naval Brass Rod

Specification No. 73.

Composition in percentage:

Copper	59.00 to 62.00
Tin	0.50 to 1.50
Iron, max.	0.10
Lead, max.	0.30
Other Impurities, max.	0.10
Zinc	Remainder

Mechanical Requirements

TENSILE TEST DATA

Diameter or Thickness, In.		Minimum Tensile Strength, Lb. Per Sq. In.	Minimum Yield Point, Lb. Per Sq. In.	Minimum Elongation in 2 In., Per Cent
Over	To and Including			
	1	62,000	31,000	25.0
1	2½	60,000	30,000	30.0
2½	3½	56,000	25,000	35.0
3½		54,000	22,000	40.0

Strain Test.—A full-size test-specimen must stand immersion for 15 min. without cracking in an aqueous solution containing 100 grams of mercurous nitrate and 13 cc. of nitric acid (specific gravity 1.42) per liter.

Bend Test.—The rods shall stand cold-bending without fracture through an angle of 120 deg. around a pin, the radius of which is equal to the diameter or thickness of the rod or bar.

Dimensions and Tolerances.—The diameter of round sections shall not vary from that specified by more than the tolerances specified in the following table.

DIMENSIONS AND TOLERANCES

Diameter, In.		Tolerances, In. Plus or Minus
Over	To and Including	
0	½	0.0015
½	1	0.0020
1	2½	0.0025
2½		0.0030

In case of other than round sections the distance between parallel faces shall be permitted to vary, in their respective sizes, double the amount of the above tolerances.

General Information

This material is intended for use wherever brass rod that is stronger, tougher, and less corrodible than commercial brass rod is required.

SEAMLESS BRASS TUBING

Specification No. 74.

This tubing is intended for all purposes for which annealed seamless brass tubing is used.

Composition in percentage:

Copper, min.	60.00
Lead, max.	1.00
Iron, max.	0.10
Zinc	Remainder

Mechanical Requirements

Tensile Test

Ultimate strength, min., lb. per sq. in., 40,000.

Elongation in 2 in. or proportionate gage length, min., per cent, 25.

Expanding Test.—A pin having a taper of 1 to 8 shall be driven into one end of a tube until the diameter is increased 15 per cent. The tube shall withstand this test without showing cracks, splits or other defects.

Appearance.—These tubes shall be clean, smooth and free from injurious defects, both inside and outside.

OUTSIDE AND INSIDE DIAMETER TOLERANCES

Diameter (D), In.[1]		Tolerances, In. Plus or Minus
Over	To and Including	
0	½	0.002
½	¾	0.0025
¾	1 in.	0.003
1 in.	1¼	0.0035
1¼	1½	0.004
1½	1¾	0.0045
1¾	2	0.005
2		0.0025D

[1]Applies to both inside and outside diameters.

No combination of variations on the same tube shall make the thickness of the wall vary from the nominal by more than the amounts given in the following table.

WALL THICKNESS TOLERANCES

Wall Thickness, In.		Tolerances, In. Plus or Minus
Over	To and Including	
0	1/64	0.001
1/64	1/32	0.002
1/32	1/16	0.003
1/16	1/8	0.005
1/8	1/4	0.008
1/4	9/32	0.0125
9/32	9/8	0.015

Special Limits.—On all stock where the above commercial variations are not permissible, the limits shall be specified in the order.

COPPER TUBING

Specification No. 75.

Composition in percentage:

Copper, min.	99.50

Mechanical Requirements, Hard-Drawn Tubes

Expanding Test.—A pin having a taper of 1 to 8 shall be driven into one end of a tube until the diameter is increased 15 per cent. The tube must withstand the test without showing cracks, splits or other defects.

Bend Test.—One test-specimen cut longitudinally and one cut transversely from the tube shall be tested. Test-specimens must withstand cold-bending through an angle of 180 deg. on a radius equal to the thickness of the wall of the tube without cracking.

Mechanical Requirements, Annealed Tubes

Expanding Test.—A pin having a taper of 1 to 8 shall be driven into one end of a tube until the diameter is increased 15 per cent. The tube must withstand the test without showing cracks, splits or other defects.

Bend Test.—One test-specimen cut longitudinally and one cut transversely from the tube shall be tested. Test-specimens must withstand bending through an angle of 180 deg., that is flat on itself, without cracking. The metal must not crack when hammered to a fine edge.

Appearance.—These tubes shall be clean, smooth and free from injurious defects, both inside and outside.

OUTSIDE AND INSIDE DIAMETER TOLERANCES

Diameter (D), In.		Tolerances, In. Plus or Minus
Over	To and Including	
0	½	0.002
½	¾	0.0025
¾	1	0.003
1	1¼	0.0035
1¼	1½	0.004
1½	1¾	0.0045
1¾	2	0.005
2		0.0025D

No combination of variations on the same tube shall make the thickness of the wall vary from the nominal by more than the amounts given in the following table.

WALL THICKNESS TOLERANCES

Wall Thickness, In.		Tolerances, In., Plus or Minus
Over	To and Including	
0	1/64	0.001
1/64	1/32	0.002
1/32	1/16	0.003
1/16	1/8	0.005
1/8	1/4	0.008
1/4	9/32	0.0125
9/32	9/8	0.015

Special Limits.—On all stock where the above commercial variations are not permissible limits shall be specified in the order.

THE DISCUSSION

CHAIRMAN BACHMAN:—I have here a communication from Mr. Parrock in the Division, in which he states: "Specification No. 64, the elongation of 8 per cent is high; we recommend 4 per cent minimum. Specification No. 65:

in view of the fact that this bronze is generally chilled, the elongation of 10 per cent is high; it should read 5 per cent minimum. General: we still believe that yield-points should be omitted on all tests of brasses and bronzes and the specifications confined to tensile strength and elongation.

MR. WOODWARD:—It appears to me that the minimum elongations given in the report should be able to meet with good sound practice. They have been accepted by other manufacturers as possible to obtain.

MR. AULL:—Such criticisms as these were advanced and discussed at the meetings of the Division.

CHAIRMAN BACHMAN:—As a matter of information, I might say that my records here show that the Division voted: seven for; none against, and one not voting, with regard to these particular recommendations, Nos. 64 and 65.

R. O. SPERRY:—Referring particularly to Specifications Nos. 62 and 64, it seems to me that in widening the limits, particularly for copper and tin, we are asking the engineers to surrender a great deal. What we are attempting to do is to approximate perfection and I do not see the occasion for changing the old specifications.

MR. AULL:—The reason for changing is that a variation of 1 per cent either way in the copper is too close for average foundry practice. What we are trying to do is to get a good practical specification and at the same time one which is sufficiently scientific.

MR. SPERRY:—Has complaint ever been registered by the users as to the old specifications?

MR. AULL:—I do not know, but I doubt if the old specifications were ever used to any extent.

MR. SPERRY:—I think that in the automotive field specification No. 26 has been used generally.

MR. AULL:—Perhaps it has, Mr. Sperry, but do you think it has ever been closely adhered to? Have manufacturers asked the foundryman to live up to it exactly?

MR. SPERRY:—I think they have.

MR. AULL:—We have never been asked to live up to it.

The changes in specification No. 70 as printed are rather numerous. The stencil report accompanying the printed report requires some corrections, but is the report approved by the Division. Following the Temper and Anneal Table, the American Society for Testing Material Brinell Hardness Table should be added; and preceding the table at the end of the specification, the note reading, "The average of Tension Tests of two samples of cold-rolled brass thinner than 0.080 in. shall conform to the following minimum requirements" should he added.

We recommend changing the word "physical" to "mechanical" in the side head "Physical Requirements." I understand from the Bureau of Standards that "Mechanical Requirements" is more correct than "Physical Requirements."

MR. WOODWARD:—Yes, and I think the same change can be applied to other specifications also.

MR. AULL:—In the tables of Thickness Tolerances a correction is required in the gage numbers which should be "from 15 to 18." The next line should be "from 19 to 24" and the decimal sizes should be changed from 0.0359 to 0.0403 in. and from 0.0320 to 0.0359 in. respectively to correspond with the corrected gage numbers. These are changes in detail to bring the specifications in line with the American Society for Testing Materials specifications. There is no controversy involved, simply a matter of detail to be straightened out in the report.

T. C. MENGES:—I notice in the babbitt specifications that no babbitt is recommended that is used in stationary engine practice. The amount of tin in any of the babbitts recommended is about 60 per cent, or a babbitt with about 5 per cent of tin. The stationary engine builders use babbitt having about 20 per cent of tin. I would like to see a babbitt recommended having about 20 per cent tin for this class of product.

MR. AULL:—I suggest that this be referred to the Society by letter so that it may be referred to the Non-Ferrous Metals Division in a regular manner.

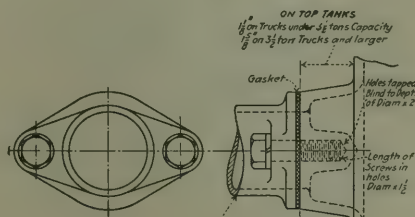
RADIATOR DIVISION REPORT

(26) *Cast Radiators*

The Radiator Division of the Standards Committee which was organized in 1920 to develop standards for use in general practice has prepared a number of recommendations which it is believed will be of value to the manufacturers of engine cooling equipment and to designers of automobiles, trucks and tractors. There are at present many differences in radiator mountings, fittings and arrangements which it is felt can and should be made standard. The recommendations reported have been carefully prepared by the Division and approved for adoption in order to bring together these many differences as new equipment is developed and brought into production. The proposed standards, when effective, will permit of conservation of materials, manufacturing equipment and stock as well as more satisfactory service to customers. They are intended to serve as approved guides to vehicle designers and builders which will in many ways lead to better and more economical practice.

Inlet and Outlet Flanges.—In present practice many tanks are cast with inlet and outlet fittings integral. This causes more expensive production, relatively high loss due to breakage and more bulky crating in shipment. Many tanks are equipped with various bolted-on fittings furnished by the customer, and uniform practice is expected to eliminate much trouble in securing and using fittings by providing a simple and suitable standard type. The Division recommends that

> Radiator inlet and outlet fittings shall be cast separate from the radiator tank. They shall be attached to the tanks by flanges which shall conform to the present S.A.E. Standard two bolt type carbureter flanges of the 1, 1¼, 1½, 1¾ and 2-in. sizes. The finished face of the pad cast on the radiator tank shall extend ⅛ in. outside of any other projection on the tank. The drilled holes in the fittings shall be 1/32 in.



INLET AND OUTLET FLANGES

larger in diameter than the capscrew or stud diameter. The tapped holes in the pad on the tank shall be blind with a maximum tapped depth of two times the capscrew or stud diameter. The length of the capscrews or studs in the tapped holes shall be 1½ times the diameter.

Overflow Tubes.—In order to secure uniform practice in the sizes of tubing used for and the method of attaching overflow tubes in the bottom tank, it is recommended that

In tubular radiators having internal overflow tubes, the tubes shall be of seamless brass or copper, attached to the bottom tank by ½ in. American standard pipe thread brass plugs. The jacket tube shall be ⅝-in. diameter and the overflow tube shall be ⅜-in. diameter.

In order to effect manufacturing economies without impairing the capacity of radiator drain cocks where used, it is recommended that

The size of the tapped hole for radiator drains shall be ⅜-in. American standard pipe thread.

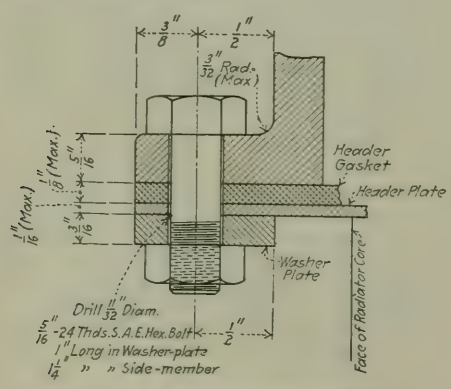
In connection with this subject, the Miscellaneous Division, at the request of the Radiator Division, is working toward the standardization of the minimum diameter of hole in the nozzle of drain-cocks. Discussion at the Radiator Division meetings indicated that this dimension varies as between different makes, in some instances being unreasonably small in proportion to the other dimensions of the drain-cocks.

Header Flanges.—General practice is in many instances nearly the same, and in order to economize in materials and manufacture, it is recommended by the Division that

Bolt-hole centers shall be spaced 2½ in. apart wherever possible.

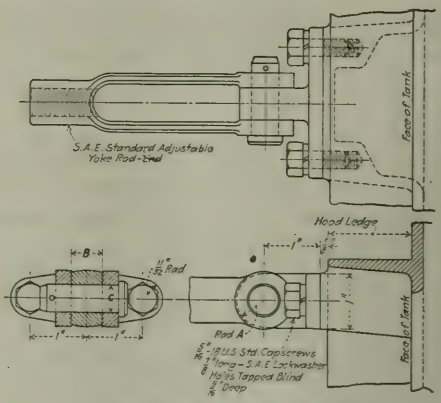
Tests have been conducted by members of the Division which indicated that cooling ribs or flanges on cast tanks are not particularly effective. Therefore in order to facilitate production in standard practice it is recommended that

Cast radiator tanks shall be designed without ribs or cooling flanges.



Cast Radiator Header Flange Dimensions

Tie-Rod Fittings.—Practice in tie-rod fittings on the top tank varies considerably in design, cost of production and in effectiveness. The Division recommendation is approved as being practical and economical in that it uses S.A.E. standard yoke rod-ends which are stocked by many forging manufacturers and are easily obtained. The proposed fitting is easy to manufacture and is readily removed and replaced and makes certain of bringing the top of the tank to the same position when it is reset which is necessary to prevent undue straining of the radiator shell and core. The following recommendation is therefore submitted:



Cast Radiator Tie-Rod Fittings

Nominal Truck Capacity, Tons	A	B	C +0.001 −0.002
To 4 inclusive	11/32	7/16	3/8
Over 4	13/32	9/16	1/2

Tie-rod fittings shall be in accordance with the accompanying illustration.

Radiator Tests.—When the Division was considering this matter it was stated that leakage tests, especially as conducted by many radiator purchasers, vary from 2 to 25 lb. pressure. The higher pressures frequently cause leaks and lead to excessive rejection of radiators. The experience of the Division members indicates that the recommended practice is ample to indicate any leaks due to defective manufacture. It is therefore recommended that

A pressure of 5 lb. per sq. in. shall be used in making all tests for radiator leaks.

Header-Plate Widths.—Comparison of widths of stock used for header-plates indicates that practically all sizes can be cut economically from the following sheets, which will facilitate the purchase and stocking of this material. It is therefore recommended that

Header-plate widths shall be 5, 5½, 6, 6½ and 7 in.

Hood-Ledge Widths. — Compilation of data of the hood-ledge widths used on different makes of trucks indicates variation in practice which is not considered necessary. It is felt that the following recommendation is good practice for manufacturing and operation, and that it is desirable to standardize this feature, since it more or less controls the height of the water inlet and

tie-rod pads cast on the top tank, and which are generally faced on a disk grinder.

The hood-ledge on cast radiators shall be 1 in. wide on motor trucks having a nominal capacity of less than 3½ tons, and 1½ in. wide on motor trucks having a nominal capacity of 3½ tons or more.

(27) *Passenger Car Radiators*

Radiator Mountings.—As passenger car radiators are usually mounted rigidly in the car frame, a flexible tie-rod is recommended to prevent straining the radiator shell through "weaving." It was felt that a more definite specification for the tie-rod or fastening should not be attempted at this time for passenger cars, but that a general guide should be provided against using non-flexible radiator supports.

The tie-rod connecting the body (dashboard) and the top of the radiator shall be flexible.

Hood-Ledges and Hood Lacings.—General practice for the hood-ledge and lacings for passenger cars is in general fairly uniform although not always as wide as is now recommended. It is felt that the proposed minimum width should be maintained so as to give ample support to the hood, and also provide for sufficient clearance between the edge of the hood and the radiator shell to prevent rubbing or punching the shell when the hood gets out of shape or through "weaving" in the car frame.

The hood-ledge shall have a minimum width of ⅞ in. Hood lacing shall be not less than ⅜ in. wide and not less than ⅛ in. thick.

TIRE AND RIM DIVISION REPORT

(28) *Wood Felloe Dimensions for Pneumatic Tire Rims*

In order to have the present standard list of felloe-band sizes conform to the S.A.E. Standard sizes of pneumatic tires and rims, the Tire and Rim Division's recommendation to extend the present standard to include the 34 x 5-in. wood felloe having a width of 2½ in. and a depth of 1⅝ in. plus or minus 1/16 in. was approved for adoption.

TRACTOR DIVISION REPORT

(29) *Tractor Belts and Pulleys*

As the Tractor Division believes pulleys of smaller than 8-in. diameter are not to be recommended for tractor purposes because of the high belt tension required to prevent excessive slippage, the Division has recommended that the present S.A.E. Standard for Tractor Belts and Pulleys, page K40, S.A.E. HANDBOOK, Vol. I (new edition), be revised to conform to the following:

Belt pulleys and clutch diameters for new equipment shall not be less than 12 in. and the pulley width shall not be less than ½ in. wider than the belt required.

Tractor drive belts for all purposes shall be 5, 6, 7, 8 or 9 in. in width.

This recommendation was approved for adoption.

THE DISCUSSION

E. A. JOHNSTON:—In addition to the printed report of the Tractor Division I would like to say that the Tractor Subdivisions have been very active and accumulated considerable data. Very little of the work has, however, been completed. The Subdivision on Plowing Speeds ran tests continuously during the past summer, as long as the weather would permit, several hundred tests having been made.

(30) *Tractor Engine Governors*

Experience, such as the bursting of threshing machine cylinders due to speeding up of the engines when not equipped with governors when the load was reduced or taken off entirely, has indicated the danger of operating such apparatus without a governor. The Tractor Division has recommended as a guide toward good engineering practice that the following be adopted as S.A.E. Standard:

Farm tractors and engines intended for belt operation shall be equipped with a governor. It is suggested that they should also be so designed that a suitable speed indicating device may be attached.

This recommendation was approved for adoption.

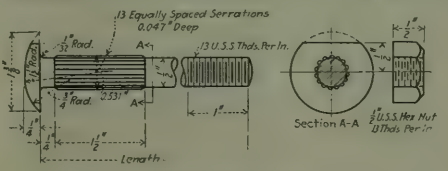
THE DISCUSSION

MR. JOHNSTON:—The reason for the proposed standard for Tractor Engine Governors is that on implements run by a tractor that is not equipped with a governor, the cylinders and cutting wheels will burst when the speeds are excessive; and on many tractors there is no space in which to attach a speed indicator, so that no provision is made in designing the tractor to get the speed of the engine.

TRUCK DIVISION REPORT

(31) *Rim Clamp Bolts*

The standard rim clamp-bolt adopted by the Society in August 1920 has a full-round head. The practice in assembling has been to drive the clamp-bolt home so that one edge of the head is turned up over the under edge of the felloe band on wood wheels or a shoulder turned in the felloe of metal wheels. This is not considered best practice, especially on wood wheels, as the necessary force required to turn up the edge of the bolt head tends



RIM CLAMP-BOLTS

to disturb the wood felloe and to bend the whole head of the bolt instead of the edge of the head. A Subdivision which has investigated this practice reported to the Truck Division its proposed revision as printed above. The Truck Division has considered this proposal and recommended its adoption by the Society as the standard clamp bolt for pneumatic-tire rims, on both wood and metal wheels as original and service equipment.

The recommendation was approved for adoption.

THE DISCUSSION

RUSSELL HOOPES:—I think that for the old type of bolt, the inner face of the wood felloe has been nearly flush with the edge of the felloe band so that the edge of the bolt head does not bend down. If this new standard, which I deem is good, is adopted, the width of the wood felloe will have to be reduced so that the bolt head will go underneath the felloe band and keep it from turning.

MR. BRUMBAUGH:—This matter was brought up by the use of the same bolt in wood or metal wheels. The thickness of the wall in the metal wheels is relatively so small that the ¼-in. dimension between the serrations and the

head of the bolts, which is necessary in their manufacture, leaves practically no provision for holding the bolts from turning in metal wheels, unless some grip on the head is obtained. The proposal affords an advantage in metal wheels and yet does not make the bolts less serviceable in wooden wheels.

C. C. CARLTON:—I think Mr. Hoopes is correct in his statement that this would require a decrease in the width of the wood felloe. I have always objected to the type of bolt that the Truck Division is objecting to. When it was put into use by the rim companies, I objected strenuously. They said that it was necessary to hold the bolt, but I think this is a very much better type.

MR. BRUMBAUGH:—It does not seem to me that it is necessary to make the wood felloe narrower, because dependence is placed on the grip of the serrated portion of the bolt in the wood felloe.

MR. CARLTON:—Not entirely.

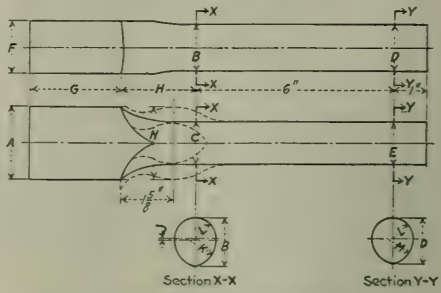
J. G. SWAIN:—Serrations are put on the bolt, not to keep it from turning, but to keep it from backing out of the wood felloe. The bolt heads, as they are now made, are perfectly round and the method of applying them is to give the bolt a hard blow after it is in the wheel, so as to upset the edge of the bolt-head and lock it under the rim or felloe band. That practice has been followed with very good success. We considered this form of bolt at the time that we arrived at a standardization of bolts for giant pneumatic rims. Our objection to it was that if in starting a bolt into a wooden wheel the square side of the bolt-head is not set in a proper angular position to go under the felloe, these flutes will cut grooves in the bolt-hole in the felloe, and when the bolt is redriven after once taking it out, it will take up the same position as before. We have found that if the round-headed bolt is used it does not make any difference how it is driven in; that when it finally reaches the seating position and it is given this extra blow, it will be set. I agree with all that has been said about this type of bolt being a little more positive as far as locking effect is concerned, and if the wheel manufacturers are willing to accept a bolt that is chamfered off, there is no doubt that manufacturers of the bolts will furnish them.

MR. BRUMBAUGH:—The flat on the bolt-head is of such height that with a standard distance between the bolt and the edge of the felloe-band there is practically a 1/16-in. clearance. We have however been considering principally the wood wheel here. The metal wheels have a shoulder turned on them for this purpose, into which the flattened faces fit. This makes the same bolt equally efficient for both kinds of wheel.

A. J. SCAIFE:—Since the Truck Division meeting in December I have worked with peculiar interest on this problem in connection with both wood and steel wheels, and I find that the edge of the bolt-heads does not bend, but that the end of the bolts bends. We tried bolts on steel wheels without cutting the heads and driving them in to get an offset on the head, but the clamps come loose. We had two cases where the felloe bands left the wheels and went over the bank.

(32) *Wood Spokes for Passenger Car Wheels*

In August 1918 the Society adopted a standard for wood spokes for motor truck wheels in accordance with those used by wheel manufacturers and endorsed by the Automotive Wood Wheel Manufacturers Association. In order to complete the standards for wheel spokes the Truck Division's recommendation of the following dimensions for passenger car wheel spokes has been approved for adoption as S. A. E. Standard. These dimensions also conform with those endorsed by the Automotive Wood Wheel Manufacturers Association and it is understood are used by practically all wood wheel manufacturers.



PASSENGER CAR WHEEL SPOKES

Nominal Spoke Size	A	B	C	D	E	F	G	H	J	K	L	M	N
1¼	See Table Below	1⅞	1¼	1⅜	1¼	1⅛	2¾	2¼	1/32	58/64	1/32	11/16	1⅝
1⅜		1⅞	1⅜	1¼	1⅜	1⅛	2¾	2¼	1/32	29/32	17/32	¾	1⅞
1½		1⅞	1⅜	1⅜	1⅜	1⅛	3	2	3/64	13/16	19/32	25/32	1
1¾		1¹¹/₁₆	1½	1⅝	1¹¹/₃₂	2	3	2	3/32	13/16	21/32	1	1

All dimensions in inches.
All dimensions are for dry spokes and are computed on a basis of a shrinkage of 1/16 in. per in. on all green dimensions, except length dimensions, to the nearest 1/32 in. under.

SPOKE-HEAD WIDTHS AND FLANGES

A		10 SPOKES		12 SPOKES	
Green	Dry	Flange Diameter, Maximum	Boss Bolt-Circle Diameter	Flange Diameter, Maximum	Boss Bolt-Circle Diameter
2	1²⁷/₃₂	5¼	8¼	6¼	9¼
2⅛	1¹⁵/₁₆	5½	8½	6½	9½
2¼	2¹/₁₆	5¾	8¾	7	10
2⅜	2³/₁₆	6	9	7¼	10¼
2½	2⁹/₃₂	6¼	9¼	7¾	10⅜
2⅝	2¹³/₃₂	6½	9¾	8	11¼
2¾	2¹⁷/₃₂	7	10¼	8½	11¾
2⅞	2²¹/₃₂	7¼	10½	8¾	12
3	2¾	7½	10¾	9¼	12½

All dimensions in inches.

UNACCEPTED RECOMMENDATIONS

In addition to the foregoing Division recommendations which were approved, a number of others were either referred back to Divisions for further consideration or definitely rejected. These are given below with the discussion at the Standards Committee meeting.

ELECTRICAL EQUIPMENT DIVISION

Magneto Couplings—Flexible Disc

The subject matter of the proposed extension of the present standard as reported by the Electrical Equipment Division and referred back to it at the Standards Committee meeting on Jan. 11 is as follows:

> Cupped or a similar form of grip-washers shall be used on the flange bolts on each side of the disc to reenforce the material against tearing out.

THE DISCUSSION

F. W. ANDREW:—This matter concerns particularly a flexible disc of the rubber type. I think this is the only case in all our standards where we practically indicate to the trade that they should use a certain type of coupling and I think that this is against the policy of the Society.

That we have had some trouble with this coupling is evident from the report that we are called upon to vote on, and under the circumstances we should eliminate the whole existing standard and substitute something of this character: The length overall of magneto couplings shall be 2⅜ in. and the diameter overall shall not exceed 2¾ in. By so doing we will not be putting ourselves in the position of recommending any particular type of coupling. I think that the matter should be put in that form rather than in the form shown.

MR. LIBBY:—I think the recommendation ought to be referred back to the Division. Mr. Andrew has raised some points that were not considered by it at the last meeting.

MR. CRANE:—I do not see why we cannot standardize the dimensions of a flexible-disc type of coupling, provided it is used. I think the Society would be very remiss if we did not do so. If we want to go further and specify limiting dimensions for any and all types of coupling, I think that is an excellent thing to do, but the fact that so many people do use flexible-disc couplings makes it very desirable that they should all be alike. I should regret very much to see the standardization of the flexible disc removed at this time or at any time.

MR. LIBBY:—In answer to Mr. Crane's remarks, I would say that we have a standard which gives the diameter of the disc and the location of the bolt-holes. Some criticism of the standard arose because certain types of discs pulled out around the bolt-holes. In order to eliminate that trouble, this recommendation was made, with the addition of these three lines to our present standard as it already exists. As I understand Mr. Andrew's remarks, he would change the dimensions that we have already in the Handbook. Before doing that I think the subject ought to be reconsidered by the Division.

MR. CRANE:—I understood Mr. Andrew to take the ground that the flexible-disc type of coupling was in some way singled out as a special feature and that it should be deleted from the S. A. E. Handbook, substituting a standard giving the length overall and the outside diameter only for any type of coupling.

MR. ANDREW:—The point I wished to make is that the recommendation seems to put the Society in the position of favoring a certain type of coupling, in view of the fact that no other types of coupling are shown, whereas there are other good types. It is evident from the report presented here that there has been some trouble with the disc type of coupling, and the present standard leads people to believe that this type of coupling is the one recommended by the Society.

MR. LIBBY:—Mr. Andrew, would not the present standard be good in connection with any type of coupling?

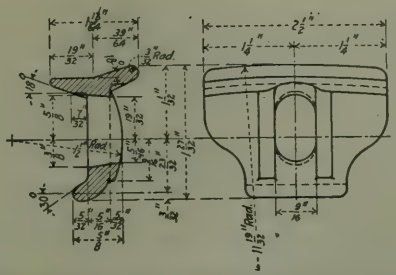
MR. ANDREW:—Not the types I have in mind, and I think we should not show one particular type only. It would be much better to give the limiting dimensions for all types.

CHAIRMAN BACHMAN:—I think that in view of the opinions expressed the matter should be referred back to the Division for further consideration.

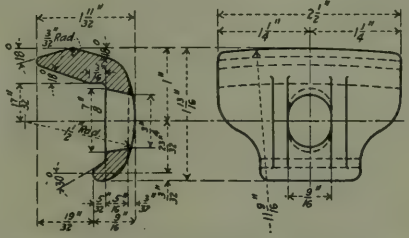
TRUCK DIVISION

Rim Sections and Contours for Pneumatic Tires

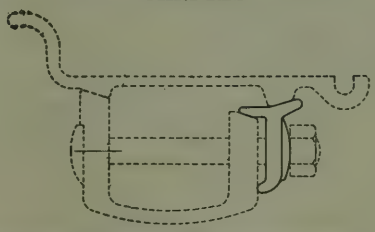
The substance of the proposal made by the Truck Division and referred back to it at the Standards Committee meeting on Jan. 11 is shown in the accompanying drawings.



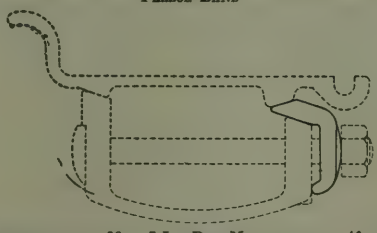
EMERGENCY CLAMPS FOR 38 X 7-IN. RIM MOUNTED ON A 36 X 6-IN. FELLOE BAND



EMERGENCY CLAMPS FOR 38 X 7-IN. RIM MOUNTED ON A 40 X 8-IN. FELLOE BAND



CROSS-SECTION OF A 38 X 7-IN. RIM MOUNTED ON A 36 X 6-IN. FELLOE BAND



CROSS-SECTION OF A 38 X 7-IN. RIM MOUNTED ON A 40 X 8-IN. FELLOE BAND

THE DISCUSSION

J. G. SWAIN:—The Tire and Rim Division considered various designs of appliances which it thought might be used to interchange different sized rims on the same wheel. There is the possibility of double oversizing of tires in using the clamps recommended by the Truck Division. This is objectionable. We have tried out clamps of this type and know from experience that they are not practical.

Consider the loading that comes on the ½-in. clamp bolt. I think it safe to say without having any definite figures that the total load on the wheel would be thrown on

two ½-in. bolts. We know that every bolt on that wheel will bend with a clamp of that type and that the truck driver will run the chance of ruining every bolt in the wheel and having to replace the bolts. If one of those bolts bends, the rim will come off. We want to recommend to the industry only things that are practical. I believe that this recommendation is impractical in its present form. I think that it would be much better to refer it to the Tire and Rim Division.

I might say on behalf of the Tire and Rim Division that it appreciates the demand for and the necessity of arriving at some interchangeability between giant pneumatic rims as quickly as possible. In its analysis of the subject it reached the conclusion that the design of trucks which carry demountable giant pneumatic rims and tires has not progressed to a stage of definite proportions of load on the front and the rear wheels. It was the consensus of opinion that when trucks have approximated a design which will permit of using only two sizes of tire on a truck, making a difference of only one tire size between the front and the rear wheels, the Tire and Rim Division will be ready to report a very practical method of interchanging rims. This proposal of the Truck Division provides for the truck owner having three different sizes of rim, a 40 x 8, a 36 x 6 and a 38 x 7 in. I think we have started out to do something but have not yet done it.

A. K. BRUMBAUGH:—There is but one disturbing point in Mr. Swain's remarks in that he says he has tried this type of lug, and that it has not proved successful. I think we ought to have more enlightenment on that point. To what extent was it tried? Was it tried in this form? And what was the purpose of the trials?

MR. SWAIN:—We tried it several years ago, in fact several times in the past four or five years on passenger-car rims. If it would not work on passenger-car rims, it will not work on truck rims. It was used on 7/16-in. bolts, six bolts to the wheel. If it was not successful in that form, it is reasonable to say that it will not work out on a truck.

MR. BRUMBAUGH:—To me personally that is not conclusive. It must be kept in mind that this proposal is intended absolutely for use as an emergency measure, to enable a man to get home or to a service station and not be forced to stand on the road for five or six hours until somebody can come with a spare tire. It is impossible to furnish space for two spares on a truck equipped with pneumatic tires. There is no spare room and there is also the matter of the investment in two tires. It is true that these clamps have not been tried out extensively, but the subject was carefully considered at a well attended meeting of the Truck Division, comprising among others several prominent truck engineers. Sample wheels were provided and there were no flaws in the proposal that could be pictured. It was the opinion at that meeting that the proposal is practical.

MR. SWAIN:—I have personally tried a similar arrangement in a small way; that is, on a smaller size wheel, and found it to be impractical. I would not want to be in the position of standing in the way of something that is good for the industry, and I would be very glad, and the company with which I am associated would be very glad, to make some experiments on wheels of the sizes in question to determine whether the recommendation of the Truck Division is practical. I suggest that before this is placed in our hands as recommended practice, we actually try it out and ascertain whether it is right. I can say on behalf of one of the companies manufacturing rims that we would be reluctant to see a proposition like this go out into practice, and we would not want to stand behind it.

GEORGE L. LAVERY:—I have made a set of these clamps and put them on wheels and tried them. I know that they do work satisfactorily. It is a fact that the bolts can become bent, but there will be no more bolts bent than in the present use of the locking rim on the standard forms of wedge rim, with which bolts will become bent in 40 per cent of the cases.

I tried the rims on a 2-ton truck and ran it for about two hours with entirely satisfactory results. There has not been time enough to try the matter out in an extensive way. It is, as Mr. Brumbaugh states, a purely road emergency proposition. If a set of bolts were lost it would not be very expensive to replace them.

MR. BRUMBAUGH:—A condition exists now with trucks operating on pneumatic tires and we must provide something and provide it quickly. If this proposal is somewhere near practical—and Mr. Lavery's trial of it seems to reinforce that opinion—it should be given favorable consideration at least.

C. C. CARLTON:—I am most heartily in favor of anything that will accomplish the purpose for which the clamp is intended. I wonder, however, if the Society wishes to put itself in the position of going through the formality of adopting a thing of this sort as a recommended practice. It seems to me that this is largely a matter of Society policy. If we open the gates by adopting this apparently untried proposition, which I should like very much to see tried and which I am very heartily in favor of if it is practical, I think we are treading on rather dangerous ground.

CHAIRMAN BACHMAN:—The Standards Committee is supposed to act as a check on the work of the Divisions and the members have in their hands the safeguarding of the policy of the Society.

Hubs—Wood and Metal Wheels

The proposal which was referred back to the Truck Division at the Standards Committee meeting on Jan. 11 is set forth in the accompanying drawings and tables.

BEARINGS FOR PROPOSED STANDARD MOTOR TRUCK FRONT HUB

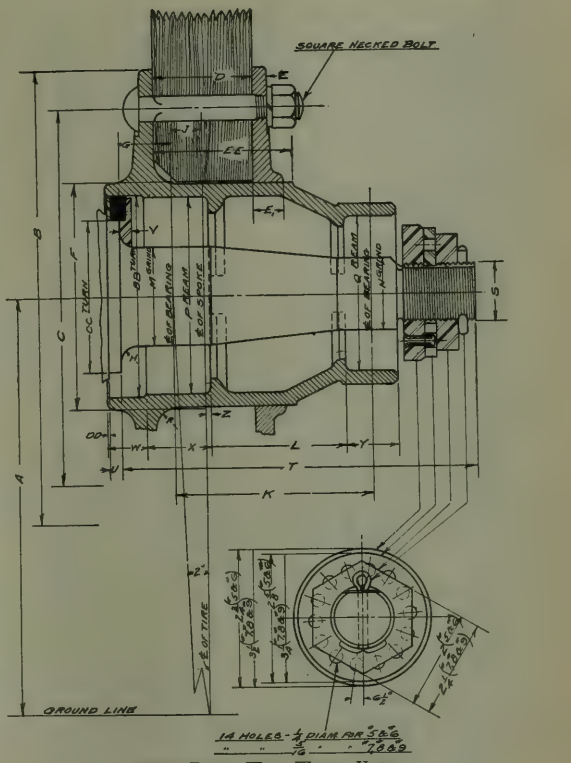
Spindle Number	Bearing	Pock Bower, Gilliam, Timken		Proposed Standard Width	Bock Bearing and Width	Bower Bearing and Width	Gilliam Bearing and Width	Timken Bearing and Width
		Bore	O. D.					
5	Inner	1.7500	3.4843	1.5000	435–43 1.5000	435T 1.5000	435–4320 1.5000	435–4320 1.5000
	Outer	1.1875	2.8593	1.1875	3191–3110 1.1875		3191–312 1.1875	3191–3120 1.1875
6	Inner	2.000	3.9843	1.5000	455–45 1.5000*	455T 1.5000*	455–4520 1.5000*	4580–4524 1.5000§
	Outer	1.5000	3.1562	1.15625	3381–3310 1.1875†		3381–3320 1.15625	3381–3320 1.15625
7	Inner	2.1250	4.3750	1.5000	539–53 1.5000	539T 1.5000	539–532 1.5000	539E–532 1.5000
	Outer	1.7500	3.4843	1.5000	435–43 1.5000	435T 1.5000	435–4320 1.5000	435–4320 1.5000
8	Inner	2.5000	4.7343	1.7500	5564–5500 1.7500	5564T 1.7500	5564–553 1.7500	5584E–5520 1.7500
	Outer	2.000	3.9843	1.5000	455–45 1.5000*	455T 1.5000*	455–4520 1.5000*	4580–4524 1.5000
9	Inner	2.5625	5.1875	2.1250	6379–6310 2.1250			6379–6321 2.1250
	Outer	2.000	3.9843	1.5000	455–45 1.5000*	455T 1.5000*	455–4520 1.5000*	4580–4524 1.5000

All dimensions in inches.
*A new bearing now manufactured.
†Bock will decrease width to 1.15625 in.
§New bearing proposed by Timken.

PROPOSED DIMENSIONS FOR WOOD WHEEL HUBS

Hub and Spindle Number	Letter	5	6	7	8	9
Ground to Center Line of Hub	A	17	18	18	18	18
Diameter of Flange	B	8 1/2	9 1/4	10	10 3/4	11 3/4
Flange Fillet Radius	R	3/8	1/2	5/8	3/4	3/4
Bolt-Circle Diameter	C	6 3/4	7 1/2	8 1/4	8 3/4	9 3/4
Number of Flange Bolts	....	12	12	12	12	12
Diameter and Length of Bolts	....	1/2x3	1/2x3 1/4	1/2x3 3/4	5/8x4	5/8x4 1/2
Spoke Thickness Between Flanges	D	1 3/4	2	2 1/4	2 1/2	2 3/4
Thickness of Spoke { At O. D.	E	1/4	5/16	3/8	3/8	7/16
Thickness of Spoke { At Bore	E1	1/2	5/8	3/4	7/8	1
Wheel Bore Limits for Hub	F	4.025 4.005	4.525 4.505	5.025 5.005	5.390 5.370	5.900 5.880
Spindle Shoulder to Center Line of Inner Bearing	G	7/8	1 1/16	1 1/8	1 3/8	1 1/2
Spindle Fillet Radius	H	1/4	5/16	5/16	3/8	3/8
Center Line of Inner Bearing to Center Line of Spoke	J	5/8	5/8	5/8	5/8	5/8
Center Line of Inner Bearing to Center Line of Outer Bearing	K	3 3/4	4	4 1/4	4 3/4	5
Inner Bearing Shoulder to Outer Bearing Shoulder	L	2 29/32	2 29/32	2 5/8	3 15/32	3 15/32
Spindle Diameter Limits at Inner Bearing	M	1.7495 1.7485	1.9995 1.9985	2.1245 2.1235	2.4995 2.4985	2.562 2.561
Spindle Diameter Limits at Outer Bearing	N	1.187 1.186	1.4995 1.4985	1.7495 1.7485	1.9995 1.9985	1.9995 1.9985
Hub Bore Limits for Inner Bearing	P	3.482 3.481	3.981 3.979	4.372 4.370	4.731 4.729	5.184 5.182
Hub Bore Limits for Outer Bearing	Q	3.482 2.856	3.981 3.153	3.482 3.481	3.981 3.979	3.981 3.979
Thread on Spindle (U. S. S.)	S	1 1/8x7	1 1/4x7	1 1/4x6	1 1/2x6	1 1/2x6
Spindle Shoulder to End of Spindle	T	6 11/16	7 1/4	7 3/4	8 3/4	9 1/8
Width of Spindle Shoulder	U	1/4	1/4	5/16	5/16	5/16
Thickness of Washer	V	1/4	1/4	5/16	5/16	5/16
Width of Counterbore	W	23/32	11/16	27/32	31/32	1 1/32
End of Counterbore to Inner Bearing Shoulder	X	1 5/16	1 1/4	1 5/16	1 7/16	1 3/4
Outer Bearing Shoulder to Outer Hub End	Y	1 1/16	1 3/32	1 7/16	1 7/16	1 7/16
Center Line of Spoke to Inner Bearing Shoulder	Z	1/4	—1/32	1/16	1/16	5/16
Diameter Limits of Counter Bore	BB	3.492 3.497	3.991 3.996	4.382 4.387	4.741 4.746	5.194 5.199
Diameter Limits of Spindle Shoulder	CC	2.630 2.625	3.130 3.125	3.380 3.375	3.755 3.750	4.1925 4.1875
Hub Overlap of Dust Ring	DD	1/32	1/32	1/32	1/32	1/32
Length of Hub Barrel	EE	2 7/16	2 13/16	3 3/16	3 5/16	3 13/16
Spindle Load Rating on Solid Tire at Ground in Pounds	....	1250	1625	2125	2750	3500
Width and Thickness of Wood Felloe*	....	2 1/4x1 1/8	3 1/4x1 5/8	4 1/4x2	5 1/4x2	6 1/4x2
Outside Diameter and Thickness of Felloe Band*	....	28x5/16	30x5/16	30x3/8	30x3/8	30x3/8
Number of Spokes in Wood Wheel	....	12	12	12	12	12
Load Rating of Wood Wheel in Pounds	....	1350	1800	2650	3500	4500
Solid Tire Size*	....	34x3 1/2	36x4	36x5	36x6	36x7
Solid Tire Load Rating in Pounds*	....	1300	1700	2400	3300	4200

*S. A. E. Standard

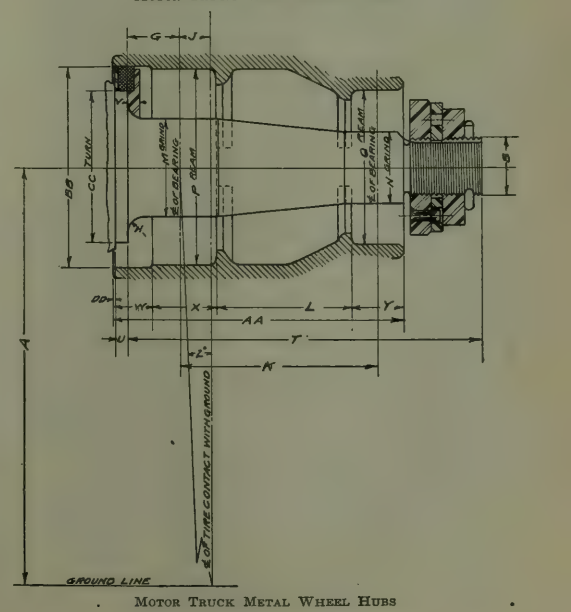


MOTOR TRUCK WOOD WHEEL HUBS

PROPOSED DIMENSIONS FOR METAL WHEEL HUBS

Hub and Spindle Number	Letter	5	6	7	8	9
Spindle Load Rating on Solid Tire at Ground in Pounds	....	1250	1625	2125	2750	3500
Solid Tire Size*	....	34x3 1/2	36x4	36x5	36x6	36x7
Solid Tire Load Rating in Pounds*	....	1300	1700	2400	3300	4200
Ground to Center Line of Hub	A	17	18	18	18	18
Spindle Shoulder to Center Line of Inner Bearing	G	7/8	1 1/16	1 1/8	1 3/8	1 1/2
Spindle Fillet Radius	H	1/4	5/16	5/16	3/8	3/8
Center Line of Inner Bearing to Center of Line of Tire	J	5/8	5/8	5/8	5/8	5/8
Center Line of Inner Bearing to Center of Line of Outer Bearing	K	3 3/4	4	4 1/4	4 3/4	5
Inner Bearing Shoulder to Outer Bearing Shoulder	L	2 29/32	2 29/32	2 5/8	3 15/32	3 15/32
Spindle Diameter Limits at Inner Bearing	M	1.7495 1.7485	1.9995 1.9985	2.1245 2.1235	2.4995 2.4985	2.562 2.561
Spindle Diameter Limits at Outer Bearing	N	1.187 1.186	1.4995 1.4985	1.7495 1.7485	1.9995 1.9985	1.9995 1.9985
Hub Bore Limits for Inner Bearing	P	3.482 3.481	3.981 3.979	4.372 4.370	4.731 4.729	5.184 5.182
Hub Bore Limits for Outer Bearing	Q	2.856	3.153	3.481	3.979	3.979
Threads on Spindle (U. S. S.)	S	1 1/8x7	1 1/4x7	1 1/4x6	1 1/2x6	1 1/2x6
Spindle Shoulder to End of Spindle	T	6 11/16	7 1/4	7 3/4	8 3/4	9 1/8
Width of Spindle Shoulder	U	1/4	1/4	5/16	5/16	5/16
Thickness of Washer	V	1/4	1/4	5/16	5/16	5/16
Width of Counterbore	W	23/32	11/16	27/32	31/32	1 1/32
End of Counterbore to Inner Bearing Shoulder	X	1 5/16	1 1/4	1 5/16	1 7/16	1 3/4
Outer Bearing Shoulder to Outer Hub End	Y	1 1/16	1 3/32	1 7/16	1 7/16	1 7/16
Center Line of Tire to Inner Bearing Shoulder	Z	1/4	—1/32	1/16	1/16	5/16
Overall Length of Hub	AA	5 3/8	5 15/16	6 7/32	7 5/16	7 11/16
Diameter Limits of Counterbore	BB	3.492 3.497	3.991 3.996	4.382 4.387	4.741 4.746	5.194 5.199
Diameter Limits of Spindle Shoulder	CC	2.630 2.625	3.130 3.125	3.380 3.375	3.755 3.750	4.1925 4.1875
Hub Overlap of Dust Ring	DD	1/32	1/32	1/32	1/32	1/32

*S. A. E. Standard.



MOTOR TRUCK METAL WHEEL HUBS

THE DISCUSSION

MR. BRUMBAUGH:—The meeting of the Truck Division at which this proposed recommended practice was passed upon was held on Dec. 16. In the short time that was available to get the printed report into the hands of this Committee the subject matter and explanation of the proposal were prepared very hurriedly. The recommendation for standard front-wheel hubs is but a part of the program instituted at the request of and an insistent demand from the trade for some standardization along this line.

The program for motor-vehicle hub standardization was inaugurated in June, 1920, by representatives of wood and metal wheel manufacturers in cooperation with manufacturers of axles, hubs, bearings, rims and tires. It has been carried out by a special Committee of Five, four of whom are representatives of prominent manufacturers of axles. This Committee is not a part of the Truck Division of the Standards Committee, but is closely affiliated with it and the Wheels Subdivision through its Chairman, Mr. Myers.

The standardization of wheel hubs for front and rear axles for both passenger cars and motor trucks was too big a task to be undertaken at the same time, and it was agreed that consideration of rear-axle hubs should be deferred in favor of the front-axle hubs for motor trucks only, which afforded better opportunity for immediate progress. Following completion of this part of the program, work is expected to proceed on passenger-car front-axle hubs and then on rear-axle hubs for both types of vehicle.

It is evident that since real hub standardization depends upon bearing sizes and location, which in turn depend upon spindle design, the logical procedure is to design a series of steering spindles for load capacities that cover the range of the various motor-truck models having load capacities of from ¾ to 5 tons.

The proposed designs for the five sizes of spindles and hubs for motor trucks were laid down on the basis of definite maximum load ratings in pounds on the tires at the ground. These ratings were selected with reference to existing practice in motor truck construction, and to the load rating of the solid tire and wheel built around each spindle and hub.

In connection with the report as submitted the Truck Division does not feel that it should propose complete designs, but rather a layout of the interior and the exterior portions of the hubs. To get bearings of proper capacity in, it is necessary to carry the practice a little further than probably the Society would usually care to go in the matter of design, but to get any progress at all it is necessary to propose considerable design. The Division is therefore proposing a spindle layout with bearings and the necessary hub dimensions to meet those bearings, and an exterior hub layout which will include the fitting of the wheels.

Spindle No. 5 will serve passenger cars of from 4200 to 5500 lb. weight; Nos. 5, 6, 7, 8 and 9 will serve motor trucks of from 1½ to 7½ tons capacity on solid or pneumatic tires. The spindles and hubs have no other rating, however, than that of their capacity in pounds on the tires at the ground. No matter what the rated load capacity of the motor truck may be, the spindle and hub to be used will depend upon the weight distribution of the loaded vehicle, which determines the load the front wheels must carry. This weight need not be as of estimate only, as it can be checked by scales measurement.

The spindles are designed so that the center of the tire where it touches the ground is vertically under the center of the inner bearing. There is, I understand, a certain patent relating to this feature, but as it expires on March 1, 1921, there is nothing to prevent proceeding with the work.

This arrangement brings the point of contact of the tire on the ground near the projection of the steering-pivot center on the ground and makes for easy steering. For a given tread and frame width it permits a great angular movement of the front wheel and therefore a short turning circle. It also reduces to a minimum the pressure on the steering-pivot and its bushings.

The location of the tire so that the load is under the inner bearing instead of between the bearings also reduces the bending moment which is due to the vertically applied load on the spindles. In the case of many axles now in use this bending moment is three or four times as great as in the case of the accompanying proposed standard spindles.

The spindles have been designed with large fillets at the shoulder, an important feature that has often been slighted in the past. It strengthens the spindle at the point of maximum stress and has the effect of moving the shoulder toward the load line, thereby decreasing the moments by shortening the lever arm to the point of load application. General practice among axle makers is to use a low-nickel or chrome-nickel steel, such as S. A. E. No. 2340 or 3140, for spindles, but the stresses in the proposed spindles will be low enough to allow the use of S. A. E. Steel No. 1035 if it should become necessary to do so under extraordinary circumstances.

The selection of the bearings resulted from a study of the types, sizes and extent of their use for this application in the trade at this time. Figures for 1919 show that about one and a quarter million bearings were used on commercial-car and motor-truck front axles. Taper roller bearings constituted about 90 per cent, straight roller bearings constituted less than 5 per cent, and ball bearings about 5 per cent of the total.

This work was started with the intention of, if possible, establishing hub and spindle dimensions such that ball and roller bearings would interchange, but it was found that there would be difficulty in getting recommendations from the manufacturers of ball bearings and roller bearings by which such interchangeable dimensions could be developed. After careful consideration, it was thought to be reasonable to confine the proposal to roller bearing hubs.

There are at least four manufacturers of taper and straight roller bearings who can furnish interchangeable bearings for the proposed hubs.

Accomplishment of the proposed standardization would be broad in its effect, as it would ultimately retire many hub and spindle designs having small and non-essential variations and reduce the number of spindles required for a given range of motor-truck sizes.

Proper standardization will encourage improvements in wheels of all kinds, because of the volume of business available in any particular size and will help to reduce the large investment in stocks of parts carried by parts manufacturers, truck manufacturers and service stations; and a manufacturer will be able to change from one source of wheel supply to another without changing parts or necessitating an additional set of service parts should any one source of supply fail. Service stations would be able to furnish wheels which would interchange on standard spindles and bearings, so that a damaged truck wheel could be replaced at a nearby service station.

The proposed spindles have been developed in practical accordance with S.A.E. tire capacity ratings, which are pretty well in line with motor truck capacities.

The proposal would be of advantage to American truck manufacturers in foreign trade. This is an important point and should not be overlooked, for American trucks must first meet competition abroad on the basis of being American trucks versus British, French, Italian and German trucks. While service parts are of great importance in the trade at home, they are an essential feature in foreign business. Front axles are rarely a sales point here, but abroad this standardized feature can be of great use, for American trucks in which are embodied such standards could be serviced from one or a few warehouses.

A meeting of the Committee of Five was held in Detroit December 15 to which practically all manufacturers of front axles were invited and many attended. The proposal was analyzed point by point and unanimous approval had.

The Truck Division and Wheels Subdivision of the Standards Committee considered the entire proposal at a meeting held December 16 in Cleveland. A few changes were made, principally in the method of illustrating component parts of the proposal. Many compromises have been made in order to overcome differences existing in practice and attempts have been made to adjust the proposal so that it will be of benefit to the industry at large and cause the least inconvenience to any one manufacturer. It is felt that much credit is due to the many persons and companies consulted for the manner in which individual preferences have been submerged and support given to the general proposal. The rapid progress which has been possible in this work has been due largely to the valuable suggestions and important concessions made toward possible establishment of such a standard.

I would like to submit the report and move its adoption as S. A. E. Recommended Practice.

CHAIRMAN BACHMAN:—There has been a considerable demand on the part of various interests in the industry for work of this character, arising from needs of manufacturers of both wood and metal wheels, and the difficulty encountered on the part of the vehicle builder in changing from one type of wheel to the other. That is only a part of the problem; I mention it as a single illustration.

This work has been started and rather than hold up the whole situation, awaiting the completion of a complete program, which would embrace passenger cars as well as trucks, rear wheels as well as front wheels, various types of bearings which may have conflicting characteristics that make it difficult to get one design which would incorporate the desirable features of all, the committee has started by attacking what it considers to be the easiest part of the problem and the one upon which it thought most rapid progress could be made—the front wheels for trucks. Consequently, in effect this recommendation is for hubs that can be used with either wood or metal wheels, mounted on a spindle with the use of taper roller bearings.

There are various items in connection with the proposal that need careful consideration. The matter of design, which this recommendation touches on possibly more intimately than in much of our work, has to be considered in the light of the peculiar characteristics of this particular matter. It seems almost impossible to conceive of arriving at any results unless such a procedure is followed; yet it must be followed in light of the policy which has been established in the conduct of the Society's affairs. We must not allow the apparent advantages to be derived from this work to overbalance the good that has been recognized in the policy that we have followed in the past. On the other hand, we must not take such a conservative position that the benefits that can be derived by a program such as this will be thrown over, purely from the standpoint of blind adherence to precedent.

There is one matter that I will take the privilege of calling to your attention; the question of load rating. The proposed ratings seem to be a logical method by which the different sizes should be differentiated and I see no particular objection to it. However, during the past few months another condition has arisen that I want to mention. The Society adopted some time ago a table of capacities for solid tires, and certain legislatures in this country have assumed that it can be taken as the basis for legislation regulating the allowable load per inch width of tires on highways. That may be perfectly proper or it may not be. I am bringing that situation to your attention to indicate that we must be careful in some of these matters because developments follow that we do not think of at the time. It is entirely possible in this instance that the proposed spindle ratings might be made the basis of similar action by legislative bodies unless we give this matter adequate consideration and know that it is the right basis, or place something in our records to indicate exactly what we mean.

I have a communication from T. Kargau which reads as follows:

> The thread on the spindle is given as a U. S. Standard thread. This thread is in my opinion too coarse for this class of service, as there would be very few threads in each of the nuts. I believe that the S. A. E. thread would be better.
>
> The method of using lock-nuts does not conform to my ideas either, the reason for this being that the outer nut forces the inner nut in and hence in most cases the inner nut does not take any of the load whatever, as it is bearing against the opposite side of the thread. We therefore have the resistance of the outer lock-nut only. I therefore suggest the use of a tongue washer and a standard S. A. E. Castellated nut.
>
> The original report by Mr. Myers included data on wheels for pneumatic tires and I believe this should be included in the S. A. E. Recommended Practice.

C. T. MYERS:—The device offered for adoption is used by several well-known axle companies and truck builders who build their own axles. It has been in use for a number of years and has given very satisfactory service. It was adopted for this reason; not that it is necessarily the best. It is as good as any we know of. There are objections to any other type of locking device and this one seems reliable, one of the requisites in this proposal. An objection to using an S. A. E. thread on the spindle arose in that it is too fine, and it is a little difficult to get the thread in the nuts to fit the thread on the spindles. This point was taken up on a number of occasions and in each instance the S. A. E. thread was voted down, it being shown that the U. S. thread gave satisfactory service.

As to the outside nut taking all the strain, either one nut or the other will take the strain anyway. I think nobody knows which nut that is. Very likely in actual operation the two nuts are jarred loose on the spindle and the outside nut backs off until it touches the cotter-pin. Under that condition the D-washer still holds the inside nut in adjustment; it cannot turn because the outside nut cannot back off a sufficient distance to release the D-washer, and as long as the D-washer cannot turn, the

inside nut cannot turn. That will hold the nut in its proper adjustment.

The pneumatic tire situation is being canvassed. We felt that we could go only as far as our knowledge indicated it was safe to go. We believe that in all the points covered we are safe in these recommendations, and that they correspond very closely to best practice. There may be some difference of opinion, but the design as laid down allows for individual modification, to enable designers to adhere more or less to their own ideas. The pneumatic tire situation is not definitely fixed in the minds of many at the present time and we do not as yet know how we should rate the axle spindles on pneumatic tires. It is the opinion of the committee that before recommending an S. A. E. Standard we should have more experience in this connection. The indications are that we shall not have to change any essential dimensions in the hubs to use pneumatic tires properly and economically.

With regard to taper and parallel roller bearings, there are at least four makes that will interchange to within 0.0002 in. in the inside, and outside diameters and in the widths.

The question of considering ball bearing in these hubs will be brought up, and it should not be assumed that this proposed recommended practice eliminates the ball bearing from use on motor trucks. We attempted in the beginning to make the hubs interchangeable for ball and roller bearings but found it impossible to do so. We will take up this matter with the ball bearing manufacturers and with any one else who has experience on this subject, and prepare a series of hubs applying to ball bearing specifications which it will be perfectly practicable to adhere to.

The bearings selected for these hubs are those which it was thought would best fulfill the conditions to be met. It was very evident in our discussions with people who buy and use these bearings that they will use the cheapest bearings which are reliable. Not very much consideration was given to the point of cheapness in selecting these bearings, but we argued for many months over the bearings sizes, and finally reduced the list to a reasonable length. The 10 applications on the five spindles will be covered by seven sizes of bearings, which will be continued as standard production by all the companies making them.

F. W. GURNEY:—The ball bearing people, although fully appreciating the great amount of work that Mr. Myers and his associates have done, still feel that if they had been given an opportunity, which through some oversight perhaps they were not given, to present their side of the situation, they might possibly have induced the committee to at least lend the weight of its influence on the side of a single proposal for standardization of the ball and the roller bearings for such work as this. We have observed that in many of the sizes that the committee recommends, if not in all, by the use of a wide type of ball bearing, we can come within a very few thousandths of the dimensions. There has been for some time an attempt made in the Ball and Roller Bearing Division of the Standards Committee to provide a common standard for ball and roller bearings, and we feel that this is an instance in which it could very well be done. This would not mean that the committee would be recommending perhaps that any one should go to some additional expense to use ball bearings; the great advantage would be that in case of necessity a ball bearing could be interchanged with the roller bearing. You all realize that in Europe the roller bearing is much less in use than in this country. There they can more readily find in any supply house ball bearings of standard sizes.

If this recommendation is to be adopted as presented, it seems to me that the heading under which it is given should be changed to read, Roller Bearing Hubs for Wood and Metal Wheels.

H. B. KNAP:—I would like to propose an amendment to the motion to approve this report. I make this amendment on the basis that due to the haste in which the report was prepared it would have to be modified somewhat to represent the action really taken by the Truck Division on Dec. 16. The amendment reads:

> The subject matter of this proposal is to be modified before being released as recommended practice or standard, and to be in accordance with the recommendation of the Truck Division it is to be reapproved by the Truck Division at its next meeting, with the proviso that parts of the subject matter may be eliminated or segregated, as may seem proper, but no additions made to it in any way.

The advantage of such a course of action seems to be that we will not incur six months' delay if the proposal is not passed at this meeting of the Standards Committee. On the other hand, there will be no possibility of it being sent out in any other way than was intended by the Truck Division and a delay of only a month or so will be encountered, as there are frequent meetings of the Truck Division.

MR. MYERS:—As there has always been some objection on the part of the Society to standardizing on design, and as this matter is presented in the report as a design, it should be explained that it is impossible to consider this subject as other than a design, so that the relation between the various component parts can be comprehensively shown. However, as it is offered for adoption it is divided into the various parts shown in the report.

G. L. LAVERY:—Will Mr. Knap include in his amendment the modified title or name of the proposed recommended practice suggested by Mr. Gurney?

MR. KNAP:—I accept the suggestion that the title be amended to include the phrase about roller bearings.

JOHN YOUNGER:—I would like to support Mr. Knap's motion and ask if he will not extend it somewhat. I suggest that action be deferred six months, and during that period be thoroughly discussed by the Society. The standardization of hubs is very important. It means not only the standardization of hubs, but the standardization of bearings, eventual standardization of wheels, and possible standardization of spindles and other devices. It is a big step to take. The last meeting was held on Dec. 16 and obviously the drawings submitted here are not in accordance with the latest views of the Division. I have been given to understand that there are too many detail data on these drawings, such as the size of the fillets.

MR. KNAP:—I think that probably we would "boil" around and not get any further than we have gone, if we made the Division too large. There are over a dozen men on the Truck Division. If we refer the matter to the entire Society, we will probably have so much confusion in six months from now that we will be in just about as bad a boat as we are in now.

MR. YOUNGER:—The subject involves not only trucks, but bearings, axles and wheels, which are handled outside of the Truck Division. The matter is very complex and should be handled patiently.

MR. BRUMBAUGH:—For almost a year this matter has been discussed by those who are most concerned, and

the proposal has the absolute approval of the people in the trade who are really affected by it. The only haste has been in the writing of the report. The long write-up mailed to the members has nothing whatever to do with the practice recommended; it is simply a statement of how the various matters were arrived at, and unfortunately it was prepared in such a way that it does not explain the subject clearly. The substance of the recommendation was scrutinized carefully by the people who are concerned in the practice.

MR. GURNEY:—I would like to request on behalf of the ball bearing industry that consideration of the subject be continued to give the ball bearing manufacturers an opportunity to offer their suggestions. I think that every one here will agree readily that if a common hub standard for ball and roller bearings can be arrived at, it will be of great advantage to all concerned. I wish to support Mr. Younger's request that more time be given to consider the subject.

CHAIRMAN BACHMAN:—In order not to confuse the issue on this matter, Mr. Knap has made a motion for amendment.

[Mr. Knap's motion was seconded.]

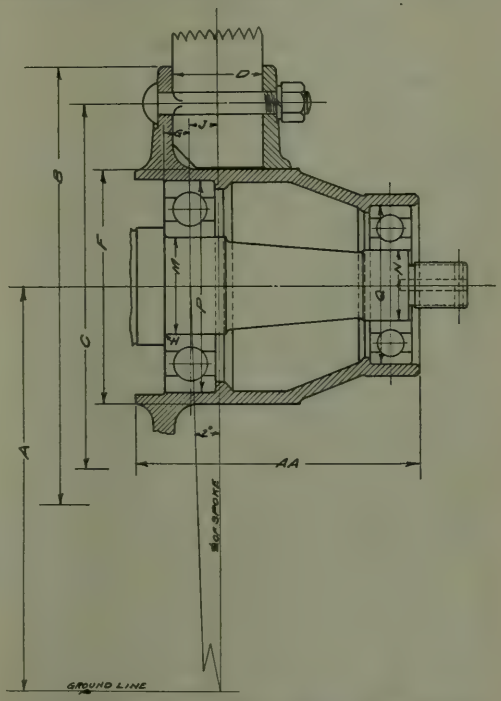
W. E. WILLIAMS:—In the engineering world in which I have been engaged there has been great advancement. I read a motto a great many years ago, which was, "Nothing will ever be accomplished if all possible difficulties must first be overcome." We have debated this subject and should go on record as being in favor of Mr. Knap's motion, sustaining the committee and passing this proposal. Assuming we had done that, what would be the situation? We would be a long way from getting the standards adopted by the axle and bearing manufacturers but we would have put into their mind the fact that something is being done and that they must take notice of it. At the end of six months we can if necessary correct any errors that have been made in the proposal of the committee.

MR. MYERS:—I have been so close to this work for so long that I am very familiar with most of the details. I have argued them back and forth with practically all those interested. It seems to me that what Mr. Williams said is very pertinent. There is much in the proposal that will be of value to the industry. The proposal will not be adopted at once; it may be two, three or four years before there is any general adoption of it. In fact, we have been careful to explain that it is not intended for immediate adoption, but rather to be thought over and worked on in order to make it practical.

It is important that we serve notice on the industry that this subject is being worked on, that the proposal has the approval of the steel wheel, wood wheel, axle and tire and rim industries. There are fundamental differences between roller bearings and the ball bearings. If we delay action on the proposal until we can reconcile those differences I doubt very much whether anything can ever be accomplished. Our plan was to consider ball and roller bearings as totally different types, and to give the industry the best standard we could for roller bearings. With one exception all the truck people are using roller bearings in the structure to which the recommendation of the Truck Division refers. I think the ball bearing people should have a clean sheet to work on when it comes to designing hubs to meet their particular needs. They have conditions to meet which do not concern the roller bearing companies. The program is a long one. It involves a number of steps. If we defer this preliminary step, we may break up our whole program.

MR. GURNEY:—The roller bearing sizes which the Division recommends are not fundamentally different from the sizes of ball bearings that are now being made. If a little more time can be had perhaps the differences can be reconciled.

MR. MYERS:—I have discussed this matter on a number of occasions with two of the important ball bearing manufacturers. While there are bearings in their lists which correspond pretty closely with the dimensions involved in the recommendation before us, the load ratings are not similar to the loads which we had to consider. The accompanying illustration and tables show the ball bearings recommended for these loads by two manufacturers. The outside diameters are ⅛ to ¼ in. larger than recommended for the roller bearings.



HUBS SUITABLE FOR BEARINGS USED ON WHITE TRUCKS
(Dimensions in inches)

Size of Truck, tons	2	3½	5
Bearing Nos.	311 308	313 309	315 311
A	18	18	18
B	9⅞	11⅛	12⅜
C	8⅛	9⅜	10⅜
D	1½	2¼	2½
F	5¼	6⅛	7
G	0.57	0.65	0.73
H	3/32	3/32	3/32
J	⅝	⅝	⅝
M	2.1654	2.5590	2.9528 2.9518
N	1.5748	1.7716	2.1654 2.1646
P	4.7244	5.5118	6.2992
Q	3.5433	3.9370	4.7244
AA	6 11/32	8 31/32	7 29/32

Our proposal is based on practice; we did not theorize at all. Whenever anything was suggested, we tried to find out what sort of service the particular part had

COMPARISON OF BALL AND ROLLER BEARING RECOMMENDATIONS FOR THE SAME SIZE OF SPINDLE

Hub No.	Bearing	Ball Bearing Recommendations SKF New	Departure (Hess Bright)	Roller Bearing Sizes Bore	Outside Diameter	Width
5	Inner	309 {3.9370 / 1.7717}	1309 {3.9370 / 1.7717}	1.7500	3.4843	1.5000
	Outer	1306 {2.8347 / 1.1811}	306 {2.8347 / 1.1811}	1.1875	2.8593	1.1875
	Inner	310 {4.3307 / 1.9685}	1310 {4.3307 / 1.9685}	2.0000	3.9843	1.5000
	Outer	1307 {3.1496 / 1.3780}	307 {3.1496 / 1.3780}	1.5000	3.1562	1.1563
7	Inner	311 {4.7244 / 2.1654}	1311 {4.7244 / 2.1654}	2.1250	4.3750	1.5000
	Outer	1308 {3.5433 / 1.5748}	308 {3.5433 / 1.5748}	1.7500	3.4843	1.5000
8	Inner	313 {5.5118 / 2.5591}	1313 {5.5118 / 2.8591}	2.5000	4.7343	1.7500
	Outer	1309 {3.9370 / 1.7717}	309 {3.9370 / 1.7717}	2.0000	3.9843	1.5000

given. The only American practice we can find on ball bearings on trucks of 1½-ton capacity and over, which is pertinent to this schedule recommended here, is that of the White Co. The drawing on page 197 shows the design of a hub with the bearings and the spacing used by the White Co. and the table below it shows hubs suitable for bearings used on the White trucks. The table at the top of this column shows the bearings recommended by two representative ball bearing manufacturers. In every case the bearings used by White are at least a size larger than those recommended by the ball bearing companies. There is a case of theory against practice. In a number of cases the ball bearings used by White are two sizes larger than those recommended by the ball bearing manufacturers. The reason for that is that White uses annular bearings at either end of the spindle while the bearing manufacturers offer the double-row type. In every case the spindle diameter is very close to what has been selected, so that grinding a few thousandths more would allow the bearings to interchange.

For the proposed No. 5 hub the outside diameter of the inner bearing is 3.482 in. The outside diameter of the suggested double-row ball bearing is 3.937 in., making a difference of practically ½ in. We could not reconcile any such difference as that. The outside diameter of the inner bearing for the No. 8 hub is 3.981 in. and that of a double-row ball bearing is 4.3307, a difference of ⅓ in. For the No. 7 hub the outside diameter of the inner bearing is 4.372 in., whereas on the double-row ball bearing it is 4.724 in., practically ⅓ in. difference; and for the No. 8 hub the outside diameter of the proposed bearing is 4.731 in., while that of the suggested double-row ball bearing is 5.5118 in., a difference of over ¾ in. in diameter.

There does not seem to be any possibilty of interchanging ball and roller bearings in the same hub, even by allowing a few thousandths difference. We feel that the 95 per cent application has been thoroughly covered in the proposal as it has been presented to various companies all over the country with no resultant adverse criticism.

MR. WILLIAMS:—One of the great difficulties encountered in selling our products abroad is that the foreign dealer is compelled to carry such a variety of supply parts. We figure on selling trucks in Australia, South America and other places where there is a big demand for them, measured by total population, but when the cost of the supply parts that must be carried with the chance of their becoming obsolete is considered, it seems that almost any man would be very bold to engage in carrying our product abroad. We should take action to notify the world that we are going to furnish something that will not involve carrying more supplies than are incorporated in the primary article. I think we would make no mistake in indorsing this report to give notice that this is what we are working toward. The details can be taken up later.

MR. SCAIFE:—Does this proposal bring in a new size roller bearing, or are the sizes recommended all in general practice?

MR. MYERS:—They are all in practice, except one new bearing.

MR. YOUNGER:—I am in favor of hub standardization from the point of view of the manufacturer. The report will eventually be adopted, but it should go through right. The bearing manufacturers are getting together and making arrangements to change the widths of their bearings; the hub people are studying the situation with a view to standardizing on design; and the wheel people are coming together. There is no reason why this report should not be delayed until the Summer Meeting, when something more definite can be adopted.

[On being put to vote both Mr. Knap's amendment and the original motion to approve the Division's report were lost. The matter was referred back to the Truck Division with instructions to reconsider the proposal, consider further suggestions and data which may be received and to prepare a report to be submitted to the Standards Committee at the 1921 Summer Meeting of the Society.]

Following the action taken at the Standards Committee meeting on Jan. 11 when the report of the Truck Division on Hubs for Wood and Metal Wheels was referred back to the Division, members of the Truck Division and the Wheels Subdivision held a meeting in the offices of the Society on Jan. 13 to discuss the action taken at the Standards Committee meeting and to establish a program for further consideration of the report. Those in attendance were A. K. Brumbaugh, chairman; E. L. Clark, H. B. Knap. A. J. Scaife, Cornelius T. Myers, A. S. VanHalteren and R. S. Burnett.

In order that ample notice may be had by everyone interested in this subject and by those who may desire to submit suggestions for consideration by the Division before the final report is formulated in accordance with instructions received at the Standards Committee meeting on Jan. 11, the following resolution was passed and has been approved by letter ballot by 10 out of 14 of the Division members:

Whereas, the Truck Division has prepared and submitted to the Standards Committee of the Society a report proposing the standardization of hubs for wood and metal wheels, and this report was discussed at length in the Standards Committee Meeting and referred back to the Division with instructions to reconsider the subject matter of the report, to give consideration to such suggestions as may be submitted from competent sources and to submit a final report on the proposal for consideration at the meeting of the Standards Committee to be held during the 1921 Summer Meeting of the Society,

Resolved, that the Truck Division herewith signifies its readiness to receive and consider suggestions and data submitted from competent sources which bear on the subject of front axle standardization for motor trucks having capacities of ¾ ton and over.

Resolved also that to permit of sufficient time for the preparation of this report to the Standards Committee all suggestions and data submitted for consider-

ation should be received by the Standards Department at the Society's offices not later than March 10, 1921.

Resolved further that the Truck Division will hold its last meeting for the preparation of a final report on the proposed hub standardization not later than March 21, 1921.

Attendance at Meeting

The members of the Standards Committee and the Society and the guests in attendance were:

Standards Committee Members

Azel Ames
F. W. Andrew
J. J. Aull
B. B. Bachman
W. H. Bancroft
W. J. Belcher
Joseph Bijur
G. R. Bott
A. K. Brumbaugh
R. S. Burnett
J. F. Caldwell
E. R. Carter, Jr.
D. F. Chambers
W. A. Chryst
E. L. Clark
C. F. Clarkson
W. F. Cole
H. M. Crane
K. W. Dyer
F. L. Eidmann
Bruce Ford
E. S. Fretz
F. P. Gilligan
F. W. Gurney
W. S. Haggott
J. L. Harkness
S. P. Hess
C. E. Heywood
W. E. Holland
F. G. Hughes
E. G. Hulse
E. T. Ickes
E. A. Johnston
L. S. Keilholtz
W. C. Keys
H. B. Knap
G. L. Lavery
B. M. Leece
A. D. T. Libby
W. C. Lipe
H. R. McMahon
C. M. Manly
T. C. Menges
Cornelius T. Myers
W. M. Newkirk
E. Nides
G. L. Norris
Charles Pack
A. J. Scaife
R. A. Schaaf
C. W. Spicer
H. J. Stagg
W. R. Strickland
J. G. Swain
A. L. Swank
S. P. Thacher
J. C. Tuttle
A. S. VanHalteren
J. G. Vincent
K. F. Walker
R. E. Wells
H. F. Wood
R. W. Woodward

S. A. E. Members and Guests

A. H. Ackerman
W. C. Acklin
P. G. Agnew
Harold Almert
R. J. Anderson
V. G. Apple
David Ayr
C. E. Banta
H. E. Bardwell
David Beecroft
J. T. R. Bell
H. E. Brunner
Earle Buckingham
E. B. Busby
Herbert Chase
V. E. Clark
H. E. Clay
R. E. Clingan
J. Coapman
Wm. Cogger
Wallace Core
R. H. Cunningham
P. K. Davis
L. W. DeWitt
N. S. Diamant
E. Dickey
V. W. Dow
E. T. Driver
J. E. Erickson
Powell Evans
Ethelbert Favary
A. W. Frehse
K. W. Gasche
H. R. Gibbons
F. Grutzner
W. J. Hart
S. M. Havens
P. M. Heldt
L. C. Hill
L. S. Homer
F. W. Horenberger
F. W. Huston
H. W. Jackson
J. G. Johnson
R. P. Johnson
T. S. Kemble
S. R. Keuch
G. W. Klinger
Otto H. Lehmann
Benj. Liebowitz
C. R. Mabley
C. R. Manes
E. S. Margolan
L. S. Marshall
J. H. Merrill
Geo. Lee Miller
W. Milne
L. F. Miller
W. J. P. Moore
R. B. Mudge
Glenn Muffly
A. L. Nelson
W. N. Nones
B. A. Parker
A. Z. Pederson
Frank Pollard
R. M. Powell
C. J. Quinn
H. Reisser
W. E. Robertson
D. C. Root
R. E. Rothway
M. P. Rumney
R. T. Russell
H. A. Schatz
J. E. Schipper
Albert Schmidt
R. A. Shailer
F. S. Slocum
A. S. Snyder
R. O. Sperry
J. A. Steinmetz
E. Touceda
S. Tour
Edward Wallace
J. S. Watson
E. W. Weaver
T. A. White
C. B. Whittelsey
W. E. Williams
G. A. Young

TORSIONAL STRENGTH OF MULTIPLE-SPLINED SHAFTS

(*Concluded from page* 130)

sional tests and strain diagrams recently, attention may be called to the fact that the torsion test curve of ductile material is quite different in form from the corresponding tension test curve for the reason that the intensity of stress on any small unit of material at any instant varies with its distance from the axis of the test-piece. Consequently, when the outermost fibers of the specimen have reached their elastic limit, the fibers near the axis of the section are still only slightly stressed. This fact undoubtedly accounts for the comparatively low elastic limit indicated at *c*, the outer layer of material having been greatly weakened by cutting the splines.

AIRCRAFT LAWS

THERE is at the present time no Federal law in existence for the registration of aircraft, nor for the licensing of operators. Under the President's proclamation of Feb. 28, 1918, persons contemplating the operation of aircraft were required to obtain licenses from the Joint Army and Navy Board of Aeronautic Cognizance. This Presidential proclamation was rescinded on July 31, 1919.

The only law which can be considered as controlling air traffic in the United States is that covered in a ruling of the solicitor for the Department of Commerce. The only other restrictions are those contained in local laws and ordinances, in force in States of Connecticut and Massachusetts, the County of Los Angeles, Cal., Atlantic City, Newark and Nutley, N. J., and Kissimmee, Fla.—*Air Service News Letter.*

JANUARY COUNCIL MEETINGS

THE regular January meeting of the Council was held on the 10th with the following present: President Vincent, Past-President Manly, First Vice-President Utz, Vice-Presidents Martin and Wall, Councilors DeWaters and Germane, Treasurer Whittelsey, Chairman David Beecroft of the Meetings Committee and Chairman Brush of the Membership Committee.

Ninety-six applications for membership and enrollment were approved, 18 for Member, 34 for Associate, 23 for Junior, 1 for Affiliate grade of membership and 20 for Student Enrollment.

William P. Hoffman, William M. Stocker, A. J. Langhammer and L. F. Renault were transferred from Associate to Member grade; Arthur L. Collins, R. D. Easton, R. D. Guy and Alexander Taub from Junior to Member grade; and W. P. Loo from Member to Foreign Member.

Past-President Manly was reappointed as a representative of the Society on the American Engineering Standards Committee to serve for a term of three years.

David Beecroft with H. M. Crane as alternate was appointed to represent the Society on the National Advisory Board on Highway Research of the National Research Council.

The following were appointed members of the Research Committee of the Society:

H. M. Crane, *Chairman*, H. L. Horning, H. C. Dickinson, E. A. Johnston, T. C. Menges, Joseph Van Blerck, J. G. Vincent, C. F. Kettering, H. W. Alden and O. C. Berry.

A session of the Council was held on Jan. 11 for the purpose of considering the action taken the same day by the Standards Committee on reports of its Divisions, prior to the submission to the Society in meeting assembled on Jan. 12 of recommendations for S. A. E. Standards and Recommended Practices. Chairman B. B. Bachman reported in detail to the Council the disposition by the Standards Committee of the various Division reports. The action of the Standards Committee was confirmed in all respects.

Organization Meeting of 1921 Council

On Jan. 14 the 1921 Council, whose administrative year began with the conclusion of the Annual Meeting of the Society on Jan. 13, held its organization meeting, the following being present: President Beecroft, Past-President Vincent, First Vice-President Horning, Vice-Presidents Bachman, Crane, Johnston and Menges, Councilors Brush, Davis and Pope, and Treasurer Whittelsey.

G. L. Martin was elected to fill the vacancy in the Council and attended the meeting.

A general discussion was had with regard to policies to be followed during the year, including consideration of the different automotive fields of work in which the Society is engaged. Vice-President Crane and Councilor Martin expressed their views with regard to aviation to the effect that there is much to be done in the matter of establishing rational regulations for the use of aircraft, and in standardization of methods, dimensions and details of various aircraft parts.

Colonel Vincent made a progress report on behalf of the committee of which he is chairman established to advise in connection with the conduct of tire and rim standardization. It was announced that H. H. Rice, representing the National Automobile Chamber of Commerce, and A. L. Viles, general manager of the Rubber Association of America, will serve as members of this committee.

H. R. Corse, who will continue to serve as Chairman of the Sections Committee this year, was present in company with J. A. Anglada and C. B. Veal, members of the 1920 Sections Committee, to report on current conditions in Sections of the Society, for the purpose in part of endeavoring to have the technical work of the Sections fit more closely into that of the Society as exemplified in programs at national meetings.

Vice-President Johnston outlined various important features in the standardization program relating to the vitally important field of farm power engineering. He stated that the fuel problem is just as important in the tractor as in the automobile field.

Vice-President Menges, who has accepted the chairmanship of the Stationary Engine Division, urged that it should be very active and arranged for holding a meeting of the Division in Chicago on Feb. 1.

Councilor Davis, who has been reappointed chairman of the Committee on the Science of Truck Operation, reported in considerable detail on its work, the importance of highway construction and maintenance problems being emphasized. The committee will keep in close touch with the impact-test work of the Bureau of Public Roads of the Department of Agriculture, and the deliberations of the Highway Engineers Association. A principal feature of the work of the committee is the collection of truck operating statistics. The whole program is one of very broad cooperation.

Standards Matters

It was announced that B. B. Bachman will continue to serve as chairman of the Standards Committee. He will be assisted by W. A. Chryst and W. R. Strickland as vice-chairmen of the Committee.

The following appointments of Standards Committee chairmen were announced:

Division	Chairman
Aeronautic	H. M. Crane
Ball and Roller Bearings	W. R. Strickland
Battery (newly established)	Bruce Ford
Chain (silent and roller chains)	W. F. Cole
Electric Vehicle	E. L. Clark
Iron and Steel	F. P. Gilligan
Motorcycle	W. S. Harley
Non-Ferrous Metals	J. J. Aull
Parts and Fittings (succeeding in part Miscellaneous Division)	Clarence Carson
Radiator	J. D. Harris
Springs	R. A. Schaaf
Stationary Engine	T. C. Menges
Threaded Parts	E. H. Ehrman
Tractor	E. A. Johnston
Truck	A. K. Brumbaugh

Administrative Committee

President Beecroft announced the following appointments to Administrative Committees, in addition to those mentioned above:

Meetings Committee—C. F. Scott, *Chairman*, Azel Ames, B. B. Ayers, Howard A. Coffin, H. G. McComb and John R. Cautley.

Publication Committee—Daniel Roesch, *Chairman*, Alexander Klemin, G. A. Young, G. W. Vaughan and H. C. Snow.

Finance Committee—H. M. Swetland, *Chairman*, Alfred Reeves, Christian Girl, G. H. Houston and E. P. Chalfant.

House Committee—H. E. Coffin, *Chairman*, C. F. Kettering, C. M. Vought, H. M. Crane and J. M. Schoonmaker, Jr.

Fuel Research

Following the meeting held on Jan. 10 of the Joint Technical Advisory Committee on Efficient Utilization of Petroleum Products, H. M. Crane was appointed as the representative of the Society to constitute with a representative of the American Petroleum Institute a committee to cooperate with the Bureau of Mines and the Bureau of Standards and direct the expenditure of funds which are or may be appropriated for research work on automotive fuels.

ACTIVITIES OF SECTIONS

Sections Calendar

BOSTON
Feb. 18—Meeting held in Springfield, Mass.
March 18

BUFFALO
Feb. 23—Temperature in Internal-Combustion Engines
April 19—Carbureter Performance

CLEVELAND
Feb. 18—Systems of Drying by R. E. Lippert

MID-WEST
March 11—Storage Batteries

MINNEAPOLIS
Feb. 7—Fuels and Fuel Substitutes by Prof. C. A. Norman
March 2—Good Roads and Equipment
April 6—Repair Equipment

PENNSYLVANIA
Feb. 25—Automotive Electrical Equipment

WASHINGTON
Feb. 4—Lubrication by Dr. H. C. Dickinson
March 18—Highways and Highway Transport

DURING the Annual Meeting in New York the Sections Committee met to consider ways for increasing and bettering the work of the Sections. To this meeting were invited the officers of all of the Sections and a number of others specially interested, including David Beecroft, the incoming president of the Society, and members of the Meetings Committee.

Chairman H. R. Corse of the Sections Committee, gave a brief outline of the growth of Section membership within the past year. The figures are as follows:

	March 1, 1920	Jan. 1, 1921
Buffalo	121	96
Cleveland	120	200
Detroit	273	366
Indiana	49	75
Metropolitan	213	211
Mid-West	107	[1]133
Minneapolis	99	[1]62
Pennsylvania	73	72
Total	1,055	1,215
Boston (Organized Sept. 22, 1920)		54
Washington (Reorganized Nov. 19, 1920)		25
Total, including new Sections		1,294

[1] Estimated.

The number of Section members on March 1, 1920, was roughly 22 per cent of the membership of the Society at that time, while on Jan. 1, 1921, this proportion had increased to approximately 28 per cent notwithstanding the fact that the number of members of the Society had, during this period, increased rapidly. This reflects in a striking way the considerable interest that is being taken in the activities of the Sections by the members of the Society as a whole. This is beneficial to all and cumulative in its effect. Increased Section membership means more and better Section papers. Better Section programs, in turn, should result in a further increase in membership.

It is felt that the Meetings Committee of the Society can render valuable assistance by informing the Program Committees of the Sections well in advance of the subjects that are to be taken up at the Semi-Annual and Annual Meetings of the Society, enabling the Sections to arrange their programs to cover the same subjects in part at least in a preliminary way. An effort will be made by a number of Sections to concentrate at their meetings during the remainder of their season on Fuel and Research, which will be leading topics considered at the Summer Meeting.

Most of the sections reported their financial status as satisfactory, and it was considered generally that the present annual appropriation by the Society of $500 plus $1 per Section member to each Section, is sufficient, in conjunction with the Section dues, to provide for all necessary expenses.

Members residing in Dayton and adjacent territory met at the Dayton Engineers Club on Jan. 18 and discussed the project of forming a Section of the Society there. Forty-five members and guests were present. As in the cases of the Boston and the Washington Sections started earlier in the winter, there was an overwhelming sentiment in favor of the formation of the Section. A tentative organization was brought about with 45 members and a resolution adopted in which the Council was asked to authorize the operation of the new Section as such. The Standard Section Constitution, By-Laws and Rules were also adopted after the election of officers for the present year as follows:

Chairman, George E. A. Hallett
Vice-Chairman, J. Herman Hunt
Secretary, Richard B. May
Treasurer, Robert F. McCann.

After the successful organization of the new Section, Chas. H. Fox of the Ahrens-Fox Co., gave a talk on the relation of automotive apparatus and fire fighting. The recent growth of the use of internal-combustion engines in this field has been phenomenal and considerable engineering thought is being applied in the connection.

The Buffalo Section listened to a talk on the use of technical motion pictures by T. R. Fessenden on Jan. 18.

Some weeks ago the Minneapolis Section heard the facts about the present status of the tractor industry. This line of thought was continued at the meeting on Jan. 17 when J. L. Record gave his opinion of the future outlook for this industry.

A talk by W. A. Reed, trade adviser of the Pan American Union, on Jan. 7 made clear to the Washington Section some of the export possibilities with South America. This is a subject of never ending interest and one of which most of us have only the slightest knowledge. The future opportunities of profitable trade relations with Latin American countries are so great that first-hand information of local conditions and needs as outlined in Mr. Reed's address provides a foundation of basic knowledge upon which engineering and sales efforts can be built intelligently.

Charles O. Guernsey, chief engineer, Service Motor Truck Co., spoke on Cushioning in Motor Truck Design before the Mid-West Section on Jan. 7. The Indiana Section had the pleasure of hearing Mr. Guernsey talk on The Design of Trucks for High-Speed Service on Jan. 4.

Those who attended the Motor Boat Meeting of the Society in December were interested in a continuation of the Diesel Engine discussion provided by the Pennsylvania Section on Jan. 18. Members of the Section together with a number of out-of-town visitors were invited to inspect the 1750-hp. German submarine Diesel engine now being tested at the League Island Navy Yard. After a dinner at the Engineers' Club the discussion of Diesel engine problems was again taken up. An added feature of the evening was the showing of the Story of Petroleum film which describes the entire oil industry from the drilling operations to the ultimate uses of the various products.

The Metropolitan Section deserves a vote of thanks from the industry for concentrating on the problem of service at its January meeting which was held on the 20th. The inspecton trip through the Willys-Overland service station at New York City, in conjunction with the talk by Cyrus J.

Rankin on Service from an Engineering Standpoint, will bring a clearer realization of the importance of service. Car owners in general are fully aware of the engineering ability displayed by automobile factories in contrast with the lack of it in the majority of service stations. Anything done to improve the work of the service station will have the hearty support of the car owner.

On the evening of Jan. 28 the Cleveland Section, taking advantage of the social opportunities of an automobile show, arranged a Ladies' Night Dinner at which Mayor W. S. Fitz Gerald was the speaker. After the dinner and talk the members and their guests visited the Cleveland Automobile Show.

The Boston Section is contributing in a creditable way to the discussion of the fuel problem. On Jan. 24, Geo. A. Round gave a talk on the subject of Liquid Fuel and led the discussion which followed.

OBITUARIES

FRANK H. BALL, formerly president of the Ball & Ball Carbureter Co., died at Detroit, on Nov. 12, aged 73 years. He was born at Oberlin, Ohio, May 21, 1847, and practically his whole life had been devoted to the invention and manufacture of useful mechanical devices. After graduating from high school at Buffalo he ran a country sawmill on his father's farm and from there went into the production of steam engines for drilling and operating oil wells. The engine which he designed was a large factor in the development of the oil industry of western Pennsylvania and he afterward developed the well-known Ball automatic high-speed steam engine, founding the Ball Engine Co. of Erie, Pa., for its production and serving as its general manager from 1880 to 1890. Subsequently he organized the Ball & Wood Co., Elizabeth, N. J., to continue the building of these engines in the East and in 1895 became president and general manager of the American Engine Co., Bound Brook, N. J., which produced a modified form of his engine known as the American Ball. In 1903 he and his youngest son, Fred O. Ball, designed and built two automobiles. After his retirement from the steam engine business about 1910 Mr. Ball and his son invented and placed on the market the Ball & Ball carbureter for gasoline engines and organized the Ball & Ball Carbureter Co. The manufacture of this carbureter was taken over by the Penberthy Injector Co., and Mr. Ball became associated with that organization in 1913 as manager of the carbureter department, a position which he held at the time of his death. He is survived by three sons and two daughters, his wife having died about three years ago. Mr. Ball had been a member of the American Society of Mechanical Engineers since 1883 and served as one of its vice-presidents from 1894 to 1896. He was elected to Member grade in the Society of Automotive Engineers, Nov. 10, 1915.

CHESTER E. CLEMENS, mechanical engineer of the Standard Parts Co., died on a farm near Madison, Ohio, on Dec. 24, 1920, aged 57 years. He was born on July 12, 1862, at Troy, N. Y. His experience was varied, having served successively as machinist, foreman and superintendent of the Ariel Cycle Co., Goshen, Ind. He next organized the Clemens & Curtiss Co., New York City, and was its superintendent and manager. From here he went with Guieterman, Rosenfeld & Co., New York City, as a buyer of machine tools and products for export. He was next connected with the Cycle & Tool Mfg. Co., Springfield, Mass., as engineer, and from there went to the Massachusetts Automobile Club at Boston, where he was master mechanic. He next entered the service of the Napier Motor Co. of America, which was also located at Boston, as an engineer. Leaving there to accept the position of engineer of the automobile department of the St. Louis Car Co., St. Louis, he subsequently returned to his position as engineer of the Napier company, and from there went to Cleveland as mechanical engineer of the Perfection Spring Co. in 1908. When the Standard Parts Co. was organized Mr. Clemens became mechanical engineer of that organization. He was elected a Member of the Society, Oct. 24, 1908.

WILLIAM T. PRICE, chief engineer of the oil engineering department of the Ingersoll-Rand Co., Phillipsburg, N. J., died Nov. 7, 1920, at the age of 37 years. He was born Sept. 28, 1883, at Montreal, Quebec, Canada. Following his preliminary education in the Toronto Technical School he entered Cornell University and was graduated in 1906 as a mechanical engineer. Previous to his entrance to Cornell he had been employed as a draftsman in the design of small hoisting equipment, blast-furnace and steel mill equipment, and during his college course he was an assistant instructor in machine design.

From 1906 to 1918 he filled several engineering and managerial positions, specializing in the designing, selling and installing of stationary oil engines during the latter part of this period.

Subsequent to 1918, he was president of the Price Engineering Corporation, New York City; president of the P-R Engine Co.; second vice-president of the Rathbun-Jones Engineering Co., Toledo, Ohio, and chief engineer of the oil engineering department of the Ingersoll-Rand Co. He was a member of the Engineers' Club, New York City, and of the American Society of Mechanical Engineers. He was elected to Member grade in the Society of Automotive Engineers, July 19, 1918.

MODERN MACHINE TOOLS

THERE are, perhaps, two outstanding advances in principle in machine work which have run in parallel with the progress of car building, namely, machining by grinding and the discovery or development of high-speed tungsten steel for cutting tools. Upon these depends the possibility of present-day rapidity of production of the class of machined parts demanded in a modern car. The first made it possible to remove small amounts of material quickly and accurately from hardened as well as from soft objects. The second enables very large amounts of material to be removed with reasonable accuracy and so quickly that a great advance was necessary in the stability of machine tools, the methods of holding and driving the work or object and the horsepower required to drive the machine.

The combination of these two advances seems to have been responsible for any "spurt" in progress, for in about 1906 we found in machines employed on the production of the car parts a good demand for and a good supply of "all geared" heads, quick-change feed-gears and a great extension of the principle of bringing different cutting tools to bear upon the object being machined. Anything in the nature of a revolution seems to have occurred about this date, and a general increase in the use of time-saving machines engaged on car construction then took place.—A. J. Hancock in *Auto.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Dec. 10, 1920, and Jan. 10, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member. (F M) Foreign Member; (E S) Enrolled Student.

ACKLIN, JAMES M. (M) vice-president and manager, Acklin Stamping Co., *Toledo, Ohio,* (mail) 1645 Dorr Street.

APPLEBY, FRED (M) designer, Holt Mfg. Co., *Peoria, Ill.,* (mail) 108 Wisconsin Avenue.

ARMSTRONG, J. ALLAN (A) soliciting agent, Allegheny Steel Co., Brackenridge, Pa., (mail) 1436 Dime Bank Building, *Detroit.*

AUSTIN, SYDNEY BERTRAND (M) engineer, Eisemann Magneto Corporation, 32 33rd Street, *Brooklyn, N. Y.*

BAKER, BRYON G. (A) general manager, Canadian Tillsoil Farm Motors Co., 704 Canada Building, *Winnipeg, Man., Can.*

BARNARD, GEORGE A., 2ND (A) acting automotive engineer, Graton & Knight Mfg. Co., *Worcester, Mass.,* (mail) 356 Franklin Street.

BARNES, WILLIAM B. (J) assistant in experimental laboratory, Cadillac Motor Car Co., *Detroit,* (mail) 246 Mount Vernon Avenue.

BICKNELL, G. M. (M) chief engineer, Carter Carburetor Co., 2838 North Spring Avenue, *St. Louis.*

BOOTH, HARRY T. (J) aeronautical engineer, Curtiss Aeroplane & Motor Corporation, Garden City, N. Y., (mail) 25 Fredericks Avenue, *Freeport, N. Y.*

BORNSTEIN, JOSEPH (A) chief engineer and works manager, American Metal Parts Corporation, Boston, (mail) 113 Howard Avenue, *Boston* 25.

BRACKENRIDGE, J. H. (J) chief engineering clerk, Cleveland Tractor Co., *Cleveland.*

CHESNUT, FRED H. (A) transportation engineer, White Co., 1490 Market Street, *San Francisco.*

CLARK, WILLIAM T. (M) factory manager, Fuller & Sons Mfg. Co., *Kalamazoo, Mich.,* (mail) 314 Stuart Avenue.

COULTER, JAMES (M) vice-president, Automatic Machine Co., *Bridgeport, Conn.*

DOANE, C. W. (M) district representative, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., (mail) 1109 Kresge Building, *Detroit.*

DOOLITTLE, H. P. (M) general patent attorney, International Harvester Co., 606 South Michigan Avenue, *Chicago.*

DUTCHER, F. H. (M) instructor, Columbia University, 117th Street and Broadway, *New York City.*

EASTON, J. A. G. (J) engineer and manager, Ericson Aircraft Ltd., *Toronto, Ont., Canada,* (mail) 267 McPherson Avenue.

EVERETT, CHARLES J. (M) vice-president, Everett Bros., Inc., 320 Broadway, *New York City.*

EVERETT, WILLIAM T. (M) superintendent, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., (mail) Frankstown Road and Hochberg Street, *Wilkensburg, Pa.*

FRALICK, L. J. (A) assistant sales manager, Hydraulic Pressed Steel Co., 3152 East 61st Street, *Cleveland.*

GAIDOS, ALONZO F. (J) draftsman and tool designer, 1185 The Alameda, *San Jose, Cal.*

GILMORE, ROGER J. (A) president, Hare's Motors of New England, 700 Commonwealth Avenue, *Boston.*

GILSON, A. (A) mechanical engineer, Packard Motor Car Co., *Detroit,* (mail) 2966 Hurlbut Avenue.

GORDON, CHARLES (A) sales engineer, Foote-Burt Co., Cleveland, (mail) 120 Wisconsin Street, *Milwaukee, Wis.*

HARRIMAN, DANIEL F. (M) chief engineer, Scientific Automotive Corporation, Hoboken, N. J., (mail) 4 Jones Street, *Jersey City, N. J.*

HAVENS, SAMUEL M. (A) assistant treasurer and works manager, Ingalls-Shepard Division, Wyman-Gordon Co., *Harvey, Ill.*

HELMBOLDT, WERNER (A) superintendent, department of motor transportation, City of Detroit, (mail) 403 City Hall, *Detroit.*

HOURWICH, ISKANDER (J) aeronautical mechanical engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio,* (mail) 122 Arnold Place Apartments.

HUGHES, RALPH C. (M) engineer, Teetor-Hartley Motor Corporation, *Hagerstown, Ind.*

HUNT, ERNEST C., JR. (M) assistant superintendent, Morse Chain Co., *Ithaca, N. Y.,* (mail) 108 North Aurora Street.

HUNTER, HARRY M. L. (A) salesman, Cincinnati branch, Jones & Laughlin Steel Co., *Pittsburgh.*

JOSLIN, FRED A. (J) draftsman, Allison Experimental Co., *Indianapolis,* (mail) 2455 North Talbott Avenue.

KEAN, JOHN SCOTT (J) designer, Naval Aircraft Factory, League Island Navy Yard, *Philadelphia,* (mail) 1630 North Sydenham Street.

KLINEDINST, L. M. (M) manager, farm tractor and implement division, Timken Roller Bearing Co., *Canton, Ohio,* (mail) 2531 Tuscarawas Street, West.

LEJEUNE, FRANK H. (J) manager, steel division, Hayes Wheel Co., *Jackson, Mich.,* (mail) 810 Wildwood Avenue.

LIEBERMAN, A. W. (M) engineer and production manager, Tracking Trailer Co., *Cleveland,* (mail) 2198 East 80th Street.

LIMBOCKER, CHARLES C. (A) president, Wolverine Tube Co., 1411 Central Avenue, *Detroit.*

LOTZ, WALTER PHILIP (A) tool supervisor, International Motor Co., New Brunswick, N. J., (mail) 314 Harper Place, *Highland Park, N. J.*

MARX, HARRY J. (A) consulting engineer, Van Muffling & Marx, New York City, (mail) 702 Chauncey Street, *Brooklyn, N. Y.*

MEDWEDEFF, MARSHALL H. (M) 5014 Wesley Avenue, *Howard Park, Baltimore.*

MITNICK, JACOB J. (J) automotive engineer, Armour Institute of Technology, *Chicago.*

NELSON, ARNE T. (M) master mechanic, Anderson Electric Car Co., Detroit, (mail) 260 McLean Avenue, *Highland Park, Mich.*

NELSON, HENRY C. (M) vice-president and general manager, Mullins Body Corporation, *Salem, Ohio,* (mail) 135 Lincoln Avenue.

NICHOLS, W. W. (A) mechanical engineer, D. P. Brown & Co., *Detroit,* (mail) 1440 Park Place.

NIHLEAN, F. R. (J) draftsman, Stromberg Motor Devices Co., *Chicago,* (mail) 6147 Champlain Avenue.

NOE, SHEROD S. (J) chief engineer, Tool & Auto Products Co., East 73rd and St. Clair Avenue, *Cleveland.*

OSTERHELD, CLARK M. (M) chief engineer, Stoughton Wagon Co., *Stoughton, Wis.*

PATTERSON, ARTHUR E. (J) assistant to C. S. Ricker, consulting automotive engineer, *Indianapolis,* (mail) 3534 North Capitol Avenue.

REES, FRED H. (A) director of sales and sales manager, Willys-Overland Co., 1631 Broadway, *New York City.*

RICE, FRED D. (A) Eastern sales representative, Eaton Axle Co., Cleveland, (mail) 197 Atlantic Street, *Bridgeton, N. J.*

RICE, WALTER J. (M) secretary and treasurer, Fox Motor Car Co., *Philadelphia,* (mail) 4553 Uber Street.

RYON, HERBERT C. (A) service manager, Watson Products Corporation, Canastota, N. Y., (mail) 329 Coolidge Avenue, *Syracuse, N. Y.*

SCOTT, JOHN (M) assistant works manager, Olds Motor Works, *Lansing, Mich.,* (mail) 409 Bartlett Street.

SCOTT, NELLIE M. (A) president and general manager, Bantam Ball Bearing Co., *Bantam, Conn.*

SELENSKY, FLOYD B. (J) draftsman, Waterloo Gasoline Engine Co., *Waterloo, Iowa,* (mail) 928 West Second Street.

STREIT, N. B. (A) sales engineer, Tide Water Oil Sales Corporation, 11 Broadway, *New York City.*

TERRY, EDWARD JAMES (A) general foreman, Holt Mfg. Co., *Peoria, Ill.*

THORNE, MAURICE A. (J) assistant physicist, Bureau of Standards, *Washington,* (mail) Turlaw Road, Northwest.

TOULMIN, HARRY A., JR. (A) patent lawyer, Toulmin & Toulmin, *Dayton, Ohio.*

VAWTER, H. L. (M) chief engineer, Parenti Motors Corporation, *Buffalo,* (mail) 63 Delaware Road.

WARDWELL, H. F. (A) general sales manager, Detroit Steel Products Co., *Detroit.*

WARNER, CAPT. WALTER W. (S M) department of engineering, Coast Artillery School, *Fortress Monroe, Va.*

WEBB, PAUL ST. ELMO (A) transportation engineer, Diamond T. Truck Co., *Nashville, Tenn.,* (mail) 1207 16th Avenue, South.

WILLIAMS, FRANK (J) draftsman, Stout Engineering Laboratories, 37 Churchill Avenue, *Detroit.*

WILSON, HERBERT L. (M) draftsman, in charge of aeronautical design, bureau of engineering, Navy Department, *Washington,* (mail) 104 13th Street, Northeast.

WILSON, LESTER T. (A) technical representative, National Lead Co., Chicago, (mail) 129 York Street, *Brooklyn, N. Y.*

WILSON, ROBERT W. (J) Vulcan Motor Axle Corporation, *Detroit,* (mail) Carola Apartments, 42 Watson Street.

ZIEBELL, A. C. (A) secretary, Universal Foundry Co., *Oshkosh, Wis.*

Applicants *for* Membership

The applications for membership received between Dec. 28, 1920, and Jan. 28, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

BAIRD, LYMAN BAIRD, production manager, Clifton-Holmes Products, *Detroit.*

BAXTER, CAPT. OTHEL, supervisor, automotive department, educational and recreational school, *Camp Dix, N. J.*

BEST, NORMAN A., engineer, Dow Chemical Co., *Midland, Mich.*

BOVELL, SAMUEL C., superintendent of equipment, Magnolia Petroleum Co., *Dallas, Tex.*

BROWN, LOWELL H., president, Belflex Corporation, *New York City.*

BRYANT, WILLIAM L., president and manager, Bryant Chucking Grinder Co., *Springfield, Vt.*

BURCH, FERDINAND L., assistant chief engineer, Preferred Motor Car Co., *Indianapolis.*

BURGELEIT, W. H., draftsman, Durant Motors, Inc., *Long Island City, N. Y.*

CAMPBELL, J. GORDON, foreman, Willys-Overland Ltd., *Toronto, Ont., Canada.*

CARNEGIE, WILLIAM, draftsman, Cadillac Motor Car Co., *Detroit.*

CARPENTER, W. W., sales engineer, H. H. Knepper, *Detroit.*

CLIFF, H. G., banker, Routt County Bank, *Oak Creek, Col.*

CORE, EUGENE D., assistant manager and consulting engineer, McIntyre Motor Co., *Kalamazoo, Mich.*

CORFF, EDWARD VINCENT, assistant engineer, American Car & Foundry Co., *Chicago.*

DALEY, FRANK R. L., chief inspector, Northway Motor Corporation, *Natick, Mass.*

DAVIS, STUART B., engine designer, Haynes Automobile Co., *Kokomo, Ind.*

DEPUY, CLARENCE E., professor of mechanical engineering, Lewis Institute, *Chicago.*

DESONIA, LLOYD J., student, Virginia Vocational High School, *Virginia, Minn.*

DUNN, WILFRED J., chief engineer, Forster Motor Car & Mfg. Co., Ltd., *Maisonneuve, Que., Canada.*

DYER, KIRK W., president, Frisbie Motor Co., *Middletown, Conn.*

EARL, HERMON, chief engineer, John W. Henney & Co., *Freeport, Ill.*

EINSTEIN, ARTHUR W., traffic engineer, Ward La France Truck Co., *Elmira, N. Y.*

ELMENDORF, ARMIN, consulting engineer, 819 Chamber of Commerce Building, *Chicago.*

FARR, HENRY W., sales manager, Johnson Carburetor Co., *Detroit.*

FESLER, J. A., special representative, Bassick Mfg. Co., *Chicago.*

FITZGERALD, M. L., president and general manager, Forster Motor Car & Mfg. Co., *Montreal, Que., Canada.*

FONTE, ALBERT L., student, Virginia Vocational High School, *Virginia, Minn.*

GAGE, V. R., assistant professor of experimental engineering, Sibley College, Cornell University, *Ithaca, N. Y.*

GESCHELIN, JOSEPH, production engineer, Duplex Engine Co., Inc., *Brooklyn, N. Y.*

GOSS, RAY B., instructor, Purdue University, *Lafayette, Ind.*

HALE, WINFIELD, factory manager and chief engineer, Stutes-Mar Tractor Co., *Sunnyvale, Cal.*

HARBUTT, JOHN E., inventor of automobile accessories, *Cicero, Ill.*

HARRIS, HOWARD C., salesman, Akron Rubber Mold & Machine Co., *Akron, Ohio.*

HARVEY, JAMES D., assistant research engineer, Stewart-Warner Speedometer Corporation, *Chicago.*

HATHORN, CHARLES E., designer, Curtiss Aeroplane & Motor Corporation, *Garden City, N. Y.*

HILL, N. A., consulting industrial engineer, *Baltimore, Md.*

HOLBROOK, FRANK, chief inspector, Russel Co. branch of McCord Mfg. Co., *Detroit.*

HUPP, R. C., automotive engineer, Detroit Athletic Club, *Detroit.*

JANERY, WALTER R., general service manager, Clark Tructractor Co., *Buchanan, Mich.*

JENKINS, HARRY E., head of radiator sales department, U. S. Cartridge Co., *Lowell, Mass.*

JOHNSON, A. E., draftsman, Holt Mfg. Co., *Stockton, Cal.*

KEISLER, SCOTT W., 62 West Alexandrine Avenue, *Detroit.*

KELLEY, E. A., sales representative, Splitdorf Electrical Co., *Newark, N. J.*

KING, W. GRIFFIN, general sales department, Aluminum Manufactures, Inc., *Cleveland.*

KINGSNORTH, HERMAN, warrant officer, Marine Corps, *Washington.*

KLOCK, FRANKLIN G., assistant to supervising engineer, Sinclair Refining Co., *Chicago.*

LANDRY, JOSEPH E., president and engineer, Landry Mfg. Co., Inc., *New Bedford, Mass.*

LARSON, J. LYMAN, instructor in agricultural engineering, University of Minnesota, *St. Paul, Minn.*

LEYERLE, FRANK J., assistant factory manager, Splitdorf Electrical Co., *Newark, N. J.*

LINCOLN, W. C., engineer, National Railway Appliance Co., *New York City.*

LINNEY, WILLIAM A., foreman, dynamics laboratory, Aluminum Manufactures, Inc., *Cleveland.*

LORING, THOMAS W., body engineer, Republic Motor Truck Co., Inc., *Alma, Mich.*

MCHUGH, THOMAS A., tire salesman, 427 Amsterdam avenue, *New York City.*

MCKENNA, A. W., chief inspector, Osgood Bradley Car Co., *Worcester, Mass.*

MCKINNON, ERNEST C., electrical engineer, Chloride Electrical Storage Co., Ltd., *Manchester, England.*

MALKMUS, GEORGE A., instructor, Rahe Auto School, *Cincinnati.*

MOODEY, A. W., automotive engineer and assistant sales manager, Sherwin-Williams Co., *Cleveland.*

MUNSON, WILLIAM C., branch manager, Russell Mfg. Co., *Middletown, Conn.*

MYERS, WILLIAM M., experimental engineer, Johnson Carburetor Co., *Detroit.*

PARKER, HUMPHREY F., assistant engineer physicist, Bureau of Standards, *Washington.*

PEARSON, LESLIE W., president, Giant Motor Truck Co., Ltd., *Vancouver, B. C., Can.*

POPPE, PETER A., technical director, White & Poppe, Ltd., *Coventry, England.*

POWELL, WILLIAM L., general foreman and body engineer, Preston Motors Corporation, *Birmingham, Ala.*

PRATT, JAMES M., assistant to general manager, Northway Motors Corporation, *Natick, Mass.*

PRESTON, VICTOR, chief body engineer, Hayes Ionia Co., *Grand Rapids, Mich.*

RUTLEDGE, C. B., president, Southern Electric Service Co., *Memphis, Tenn.*

SANDERS, WILLIAM E., experimental engineer, Burch Service Co., *Indianapolis.*

SCHAEFER, LOUIS P., service man, Elizabeth Auto Co., *Elizabeth, N. J.*

SEYMOUR, GLEN F., trouble investigator and layout man, Cleveland Automobile Co., *Cleveland.*

SHEFFIELD, EARL A., equipment representative, Bethlehem Spark Plug Co., Inc., *Bethlehem, Pa.*

SMALL, A. R., vice-president, Underwriters' Laboratories, Inc., *Chicago.*

SORENSEN, CLARENCE S., mechanical engineer, C. M. Gay & Son, *Los Angeles, Cal.*

STEWART, JAMES L., vice-president and general manager, Thomart Motor Co., *Akron, Ohio.*

STRANG, W. H., factory manager, L. C. Graves Co., *Springboro, Pa.*

SUDDUTH, ARTHUR L., instructor in ignition, School of Engineering, *Milwaukee, Wis.*

TAAFFE, RANDAL DUNNE, mechanical engineer, owner of machine shop and distributor for Hares Motors Products, *Santa Barbara, Cal.*

THOMA, LOUIS, engineer, Advance-Rumely Co., *Clearing, Ill.*

THOMAS, S. J., sales engineer, Canton Rim Co., *Louisville, Ohio.*

TIGAR, M. GEORGE, treasurer, M. George Tigar Bearing Co., Inc., *New York City.*

TRESSLER, ROBERT L., salesman, I. J. Cooper Rubber Co., *Dayton, Ohio.*

TWYMAN, THOMAS C., sales manager, G-A Ball Bearing Mfg. Co., *Chicago.*

UPTON, G. B., professor of experimental engineering, Cornell University, *Ithaca, N. Y.*

VANCIL, E. D., draftsman, Garford Motor Truck Co., *Lima, Ohio.*

VON GOCH, EDWARD P., vice-president and general manager, U. P. C. Book Co., Inc., *New York City.*

VAN SANDWYK, MARINUS C., student automobile mechanics, Sweeney Auto School, *Kansas City, Mo.*

VON THADEN, HERBERT, student, Massachusetts Institute of Technology, *Cambridge, Mass.*

WALKER, GILBERT DUNSTAN, production and efficiency engineer, Hartford Automotive Parts Co., *Hartford, Conn.*

WARNER, FRANCIS J., district engineer, Standard Oil Co., *Spokane, Wash.*

WASSERFALLEN, C. F., factory manager, Detroit Carrier & Mfg. Co., *Detroit.*

WATSON, L. E., general manager, Clovis Motor Co., *St. Marys, W. Va.*

WEBER, EUGENE A., chief engineer, Gardner Motor Co., Inc., *St. Louis.*

WEISSINGER, HORACE L., superintendent, automobile body department, Osgood Bradley Car Co., *Worcester, Mass.*

WERNER, J. F., chief body engineer, Kissel Motor Car Co., *Hartford, Wis.*

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Chicago Meeting and Dinner

THE meeting of the Society held in Chicago on Feb. 2 was not only a marked success but was the occasion of the first national sessions devoted to the operation and maintenance of automotive apparatus from an engineering standpoint. The technical sessions held during the morning and the afternoon were well attended. Vice-President B. B. Bachman was in the chair. N. J. Ocksreider, chief transportation engineer of the Packard Motor Car Co., gave an address on Engineering Analysis Applied to Truck Selling. He said that in this day of transportation engineering the requirements of each customer must be diagnosed accurately, eliminating economic waste due to wrong selling. He stated that 32 classes of trades, divided into 350 subclasses, use motor trucks. In applying the science of selling by analysis, it is necessary to know the cost of shipping every pound of goods, deducing in turn the correct size of truck for a given kind of work. Referring to the fact that a truck cannot be designed to stand up under all conditions and that selling a truck that is unsuitable for a particular task means a dissatisfied customer, the author expressed the opinion that a truck of mediocre merit will in many cases perform more satisfactorily than the best truck made operating under improper conditions. Chairman Bachman said that the application of efficiency methods, which means the application of common-sense principles, is of inestimable benefit in truck operation. Mr. Ocksreider made a broad-minded and valuable contribution in his statement of the factors to be observed in determining the proper type and size of truck to meet a given customer's requirements in the most satisfactory manner, pointing to the many advantages derived from the making of unbiased recommendations and taking all steps possible to prevent overloading.

The Application of Steam Power to an Automotive Truck was the subject of the paper by L. L. Scott, who described the development and present status of a steam-driven 2-ton truck constructed by E. C. Newcomb and him. The advantageous features of the steam power-plant were enumerated and torque curves shown, in addition to other illustrations. The matters of engine control and fuel, oil and water consumption, were discussed and the results of various acceleration tests presented. Among other opinions voiced in the discussion of this paper was the one that engineers should not close their minds to any possible line of development that will make a greater percentage of crude oil available for automotive vehicles and that all should be open to conviction regarding new methods.

Capt. J. B. Haney, of the United States Ordnance Department, described the development of artillery automotive materiel during 1920, including the tractor hand cart, reconnaissance tractor, Division artillery tractor, Corps artillery tractor, Army artillery tractor, heavy or 15-ton artillery tractor, tractor and trailer caissons of 1½ and 3-ton capacity, and self-propelled mounts for Division, Corps and Army gun and howitzer. The hand cart, which is of the track laying type, is pushed or drawn by one or two men and is to be used for carrying ammunition or miscellaneous supplies which would otherwise have to be carried by men on foot. The reconnaissance tractor is intended to fill the gap in motorized artillery left by the horse of the individual mounted man, as it is not practicable to combine horse and motor transport in the same unit. Captain Haney stated that the use of the motorcycle, which requires fairly good roads, is limited. The first Division tractors were built in 1918 but finished too late to be of service during the war. As now constructed, this type of tractor weighs 7700 lb. and has a normal speed range of from 3 to 9 m.p.h., although 12 m.p.h. has been maintained for short periods with it. This tractor is still in the experimental stage. The 1920 model Division artillery tractor, which was exhibited at the Society meeting last June and described in the October, 1920, issue of THE JOURNAL, has a normal range of speed from 1 to 15 m.p.h.

The Army places considerable importance on the relatively high speed, waterproofing and quiet operation of tractors, factors that have not yet entered decisively into commercial designs. The Army does not intend to build more 5 and 10-ton tractors of the types now in use but to develop a new tractor of a size between those of the Division tractor and the 15-ton tractor now under construction.

The tractor caissons built during the war here and abroad were too heavy for economical operation. Nothing has as yet however been developed to replace them.

The combined wheeled and track-laying type of tractor is considered a most interesting development, although its abilities have not been tested as rigorously as have those of the track-laying type. When operated as a wheeled vehicle it is steered by the front wheels; as there is no differential care must be taken in making short turns to release the clutch controlling the inner driving-wheel. When the track is in use, the steering-knuckles are securely locked and the vehicle steered by the clutches and transmission in the usual manner. The

tracks can be put on or taken off in a very short time by a trained crew.

In tank design the tendency is toward a smaller tank than the Mark VIII but a larger one than the 6-ton Renault.

The paper on Truck Fleet Operation, by N. J. Smith of the Consumers Co., Chicago, was very well received as showing the value of keen analysis and sound judgment in applying engineering principles in truck operation. The author argued that salesmen should have accurate information on the service policies of their companies and as to all guarantees they are authorized to make. It is felt that adequate cooperation between the engineering and the sales departments is extremely important in the psychology of truck selling. The buyer must understand exactly what he is buying, what it will do, and the conditions under which the truck will operate properly. Things that the truck builder must keep clearly in mind are the design of each individual part; the material and workmanship which go into it must be the best for the purpose, so that breakdowns shall be as infrequent as possible; and accessibility of all of the parts.

Mr. Smith said that one of the weak points in motor trucks today is ignition failure, which contributes to faulty performance through various effects. The author said, "While we await the advent of more efficient carburetion equipment, the present carbureters should be made as nearly foolproof as possible, with necessary adjustments few and simple." The use and improvement of engine governors were advocated. Mr. Smith said that the time required by two men for removing a engine from a truck varies from 1½ to 4½ hr. The company with which Mr. Smith is associated operates over 150 motor trucks in Chicago and adjacent territory, delivering coal, ice and other supplies. The loading is done in part by overhead locomotive cranes capable of handling of from 2 to 10 tons in 2 min. The time generally taken for a truck to get into the yard, secure its load and go out again is less than 5 min.

It is the policy of the company to do everything possible to prevent the trucks reaching such a condition that they require overhauling. Mr. Smith said that some of the trucks have traveled over 70,000 miles and are apparently in first-class condition. The author believes that his company is delivering coal and ice at less cost than any other firm in Chicago. Each truck is washed and inspected carefully every night. Mechanics go over the truck, tightening brake-bands, straightening mudguards and checking up on all the little things that may be wrong and might if not checked develop into serious troubles.

One surprising statement that Mr. Smith made is that it costs about as much to maintain a dump body with a hoist per year as it costs to maintain the rest of the truck. The shop equipment used by the company consists of shaping, milling and drilling machines, air and drop-hammers, special reamers for all bearings, woodworking machines and machines for painting. All of the mechanics are selected carefully and well treated.

The theme of Mr. Smith's remarks was that it is more economical to spend money in preventing trouble than to speculate against the law of averages and in the end pay as much or more for repairs.

J. C. Thorpe, an engineer who has sold trucks and tractors in Illinois for many years, gave an address on Tractor Service Requirements, treating in turn the service, commercial and technical aspects. Regarding the discussion as to whether the farm implement man or the automobile agent is the logical tractor dealer, he said the only true basis for a man being a dealer is selling good merchandise by good merchandising methods and having sold the goods maintaining them in operation through expert service. Previous experience in the work is not essential. The good dealer is entitled to his place, selling and keeping sold automotive apparatus. The success of a manufacturer depends upon keeping the good will of the trade; this must be accomplished through the dealer. The selection by a customer of the dealer rather than the equipment is evidence of weakness in manufacturing and merchandising policy.

Mr. Thorpe called attention to the fact that there can be no such thing as free service, for in the end the customer pays. He submitted the following definition of service:

> The co-operation between the dealer, the factory and the owner, during the life of the machine, whether the machine be in the hands of the original purchaser or not, to make the use of the machine feasible at reasonable cost.

He argued that the engineering departments should urge upon merchandising departments intelligent distribution through dealers, the stocking of an adequate supply of parts and the maintaining of a well qualified mechanical force for the purpose of making engineering development work in the form of farm power automotive apparatus effective. The designer and the producer should interest themselves in the merchandising policy of the factory, as this is the only procedure by which the engineers can secure to the extent merited justification for their work. Mr. Thorpe advocated strongly that factories should not neglect the fabrication of spare parts in the turmoil of production of complete apparatus. He feels that there is great need of a suitable system of training mechanics for tractor service work, as it cannot be assumed that a man who can assemble an automobile will make a satisfactory tractor operator. There should be a definite plan to assure that the men making repairs and adjustments in the field are well qualified for the work. Instructions as to assembling and operation should be given to secure a satisfactory fundamental result.

In connection with the development of farm implements and tools of various kinds to be operated by tractors, Mr. Thorpe said that by using the tractor in about a score of different operations it would be possible by spreading the overhead, which is the largest item of expense, to reduce the cost of plowing 30 per cent. The actual needs of the farmer should be kept in mind at all times. With relation to the use of motor trucks in farm work, the speaker was of the opinion that sufficient specific data as to cost of operation for comparison with horsedrawn haulage are lacking, and that a standard method of demonstrating the performance of tractors and trucks should be worked out on an engineering basis, for the reason that salesmen cannot proceed intelligently without proper performance records. Both tractors and trucks should be sold on the basis of fitness.

In conclusion, Mr. Thorpe urged continued consideration of the subject of accessibility of parts in tractor design, the use of better materials, reduction of weight and the furtherance of a program to increase the number of tools driven by tractors in farm work. His remarks were heartily applauded.

The Need for Greater Service Accessibility in Car Design was treated by T. F. Cullen, managing editor of the *Automobile Trade Journal*. Mr. Cullen was formerly engaged in passenger-car service work and it is

not surprising that his comprehensive discussion elicited much interest. Starting with the axiom that everything done to reduce upkeep and maintenance cost tends to increase the car owner's satisfaction, items of expense were listed as follows in descending value: insurance, garage expense, repairs and adjustments, tires, gasoline and oil. Service reputation based on the cars now in use is rapidly becoming the predominating factor in resales. With 8,000,000 cars in use today the reduction of time necessary for service work by 2 hr. per car per year would make possible a saving of total upkeep expense per year of $15,000,000, in Mr. Cullen's opinion. In the preparation of his paper, the author made a survey of 40 cars representative of various schools of design, including those equipped with 4, 6, 8 and 12-cylinder engines and covering a wide price-range. He then rated the cars according to comparative accessibility in 25 different service operations, no attempt being made to cover all operations or extensive overhauls. On a basis of a par of four for each operation, Mr. Cullen rated the cars in percentages varying from 64 to 95, according to his view as to what the respective accessibilities should be; the percentage for engines with cylinders in a row being 83 as against 69 for V-type engines. In the last named connection it was pointed out that factors not related directly to service work must be taken into account in determining the all-around desirability of any passenger-car type of engine. L. H. Stellman, chief engineer of the H. H. Franklin Mfg. Co., expressed the opinion that in view of the omission of some service operations from Mr. Cullen's chart, the total percentages derived by him were somewhat misleading. Mr. Stellman offered the following points for consideration: Dividing parts to be lubricated into (*a*) engine, (*b*) fast-moving or heavy-duty, and (*c*) minor, such as brake-rods; all nuts and bolt-heads to be hexagon-shaped and mounted with sufficient clearance for use of commercial socket-wrenches; cap-screws to be sufficiently strong to withstand abuse in removal and reinstallation quickly and without undue care; where gaskets are used to prevent oil leakage, cap-screws to be sufficiently close together for an average mechanic to get a tight joint and freedom from bulging due to excessive tightening of cap-screws; readily replaceable felt washers in the front and rear wheels; localization of wear on small relatively inexpensive and easily replaceable parts; use of bushings or simple parts of low cost to take wear; arranging wiring so that it can be checked readily, preferably to have all wiring connected with central switchboard; and easy adjustment of transmission and rear-axle bearings, with quick reassembly without consequent oil leakage.

Mr. Cullen dwelt at some length upon the value of factory engineers giving attention to the design of special tools and equipment for dealers' service stations, to facilitate service work on new and old cars. The time is rapidly approaching when the factory engineering department will consider service station equipment for the cars they build just as necessary as assembly equipment and machine tools for the factory. The service man should be consulted in connection with car design, inasmuch as he meets the car owners and knows their needs better than the designing engineer can know them under ordinary circumstances. Some factories have made it compulsory that engineers responsible for the design of a new car shall drive the car during the period of its development and do all necessary work on it themselves, the idea being that the lessons learned in this way should be used in improving the design.

President Beecroft described the "fixed-price" service system now being used more or less extensively in Wisconsin, whereby a car owner calling at a service station is apprised definitely what the shop charge will be before any adjustment or repair work on the car is done. Feeling that this is a step in the right direction, he said that the engineer should go out into the field for the purpose of interpreting and translating for his use the conditions of the environment in which the apparatus he designs works. It is his function to study conditions and meet them economically.

The dinner held on the evening of Feb. 2, which was attended by over 500 members and guests, was highly enjoyable and very instructive. In introducing First Vice-President H. L. Horning, who acted as toastmaster, President Beecroft called attention in a forceful manner to the importance of the work of the Society as evidenced by its personnel and exemplified in its great activities centered about the internal-combustion engine, in the design and production of passenger cars, motor trucks, tractors, house lighting apparatus, stationary engines, motorboats, motorcycles and aircraft.

Mr. Horning made a plea for a more complete realization that basic worth of character is the world's greatest asset and that no individual can hope to survive industrial difficulty unless he has that personal integrity upon which every business man must depend. In connection with research, he said that the man who is not sufficiently versed in physics, chemistry and thermodynamics to locate and understand the things that are causing difficulty in his work will fail; that the firm that makes good will be the firm that knows the job through and through.

President H. H. Merrick of the Great Lakes Trust Co., Chicago, was in his best vein. He said that bankers, being dealers in credit, are necessarily optimists and have faith in the great business structure of the country. He described an optimist as a man who sees in the darkness a light that may not exist; a pessimist as a man who comes along and blows the light out. The future lies in the working of the one fixed law of supply and demand, which was disturbed during the war and much impeded during the period immediately following the armistice. The proof of our nation's strength is that it suffered so little fatal damage in the unprecedented industrial strain which began last spring. Mr. Merrick expressed the view that Roosevelt was right when he said that we would be as unprepared for peace as we were for war. The crying need now is courage. Our entire surplus stock of commodities is not sufficient to replenish the empty shelves of the world. The one thing needed is restoration of worldwide credit.

Prof. J. Paul Goode, of the University of Chicago, gave a masterly address on America as a World Power, presenting many novel charts bristling with statistics that brought home in a very vivid manner the amazing potentialities of this country and the tremendous individual and national responsibilities involved therein. It is pretty certain that few if any of the members ever witnessed such an array of coordinated facts in chart form relating to the wealth and commerce of this country from its inception. Professor Goode said that America is great enough to be generous and wise enough to be just, and expressed the hope that our great opportunities and powers will be used henceforth in such manner that we shall deserve the respect and gratitude of all men for all time.

The $14,000,000,000 trade of the United States last year was the largest in its history. The eastern part of

the United States produces enough to buy in very large volume from the rest of the world. How rich this country is is not known. In 1914 our wealth was estimated at $250,000,000,000. We have the major portion of the significant minerals of the world. We make two-thirds of the world's cotton. War cannot be waged without cotton; a 16 in. gun takes one bale for one shot. We produce no silk, although we are the largest buyers, manufacturers and users of it. We have over one-half of the minable coal of the world.

Professor Goode said that there are four nations that can wage a world war: United States, Great Britain, Germany, and China, potentially; and that any two of them can prevent such a war. War cannot be waged without copper, of which the United States is the principal source of supply.

The musical program of the dinner was of a high order of merit and satisfaction, consisting of classical and popular pieces rendered by the men and boy choir, and the singing by all present of old and modern ditties, the words of which were flashed on screens in three different quarters of the room.

FEBRUARY COUNCIL MEETING

THE meeting of the Council held at Chicago on Feb. 3 was clearly as important as any session of officers of the Society during its whole history. Those taking part in the deliberations were President Beecroft, First Vice-President Horning, Second Vice-Presidents Bachman, Crane, Johnston, Menges and VanBlerck, Councilors Brush, Germane and Pope, Treasurer Whittelsey; Dr. H. C. Dickinson, Past-President Alden and Prof. O. C. Berry of the Research Committee; Vice-Chairman Chryst of the Standards Committee; Chairman Scott of the Meetings Committee, and Secretary and General Manager Coker F. Clarkson.

Membership

Forty-two applications for membership and enrollment were approved, 1 for Service Member, 12 for Member, 20 for Associate, 7 for Junior and 2 for Student Enrollment. Albert deBeaulieu and V. C. Worden were transferred from Associate to Member grade and Harry J. Marx from Junior to Associate grade.

Seventy-one applications for membership were received during January of this year, as compared with 68 for the same month of 1920.

Standards Matters

Questions involving the continuance and establishment of Divisions of the Standards Committee, the appointment of personnel of the Divisions and the designation of the Chairmen thereof, were acted upon as set forth in the article appearing in this issue on the 1921 Standards Committee. In addition, consideration was given to the official list of items of work of the Standards Committee, including assignment of new subjects. A report on the number of Division meetings held during the 1920 administrative year and the attendance at and results of these meetings was made.

Section Matters

The establishment of a Section of the Society with headquarters at Dayton, Ohio, was authorized.

Research Work

After receiving a report from the Research Committee and an extended discussion, it was decided that a Research Department of the Society should be instituted, the cost of the conduct of this during the 1921 Administrative Year not to be in excess of $30,000. The purpose in mind in the formal inauguration of this department is outlined elsewhere in this issue of THE JOURNAL

Vice-Chairman Strickland, of the Standards Committee, was designated to serve on the special committee of the Society which works jointly with a committee of the National Automobile Chamber of Commerce in conference with the Underwriters' Laboratories on the elements and features of automobiles in connection with allowance schedules relating to the amount of premiums of theft, collision and fire insurance policies.

Prices of Publications of the Society

The following revised schedule of prices for publications of the Society, to non-members and for extra copies to members, was determined upon:

	First Copy		Additional Copies	
	Members	Non-Members	Members	Non-Members
JOURNAL	Paid with dues	$0.50	$0.25	$0.50
TRANSACTIONS (per part)	Gratis	10.00	5.00	10.00
Roster	Gratis	2.50	0.50	2.50
S. A. E. HANDBOOK				
Vol. I	Gratis	10.00[1]	10.00[1]	10.00[1]
Vol. II[2]	....	....	....	....
Data Sheets	....	0.06	0.06	0.06
Binders (each)	3.50	4.00	3.50	4.00
Iron and Steel Pamphlet	....	1.50	1.50	1.50
Nomenclature Pamphlet	....	0.75	0.75	0.75
Engine Testing Forms[3] (per sheet)	....	0.03	0.02	0.03
Emblems	3.50	....	3.50	....
Preprints	0.25	0.50	0.25	0.50

[1]Price does not include any new and superseding sheets. These may be purchased at 6 cents a sheet as issued.
[2]Price for Vol. 2 of the Handbook not to be decided until publication of revised edition.
[3]Now reproduced in Handbook. Special price on orders for 50 or more copies of any standards publication.

Semi-Annual Society Meeting

It was formally decided that the next meeting of the Society should be held at West Baden Springs Hotel, West Baden, Ind., May 24 to 28.

LONG-DISTANCE FLIGHT

ASIDE from the exploratory value of long-distance reconnaissance flights, there is a very material military value. Experience and training impossible of attainment by any other means is to be had. Pilots and mechanics who participate in such flights carry on operations thousands of miles from their base. Every long-distance flight ever attemped has given the flying personnel engaged a wonderful opportunity to study the art of flying. It affords the best opportunity to check the value of navigating instruments. Every flight has its own individual problems involving mechanical operation, supply and navigation. The successful solution of all these problems is the best possible training for Air Service personnel. Practice flying around an airdrome is essential, but however important such flying may be, it cannot compare in any way with long-distance cross-country flying. These flights already successfully carried out have done more than any one thing to foster and develop commercial aviation. —Air Service News Letter.

The Nature of Flame Movement in a Closed Cylinder

By C. A. Woodbury[1], H. A. Lewis[2] and A. T. Canby[2]

Annual Meeting Paper *Illustrated with* Charts and Photographs

THE nature of flame propagation in an automobile engine cylinder has, for some time, been the subject of much discussion and speculation. However, very little experimental work has been done on flame movement in closed cylinders with the view of applying the knowledge directly to the internal-combustion engine. Recently automobile builders and others have seen the production of automobiles, trucks, and tractors increase at a rate out of all proportion to the increase in the production of the vital fuel, gasoline. With the recognition of this attention was turned to the possibilities of (*a*) using other fuels such as kerosene, benzene, and alcohol and (*b*) increasing the efficiency of the engine when using the existing standard fuel. To accomplish either of these ends information on the flame propagation characteristic of each of these fuels was essential.

It has become very generally recognized that there is one great difficulty; namely, "knocking" which attends the use of higher-boiling paraffin hydrocarbons, such as kerosene, and that "knocking" is one of the major difficulties to be overcome in designing higher compression, and hence more efficient engines. It was desirable, therefore, to determine if possible the nature and cause of fuel knock. The work described in this paper was undertaken to determine the characteristic flame movement of these various fuels and the physical and chemical properties which influence this flame propagation.

Scope of Work.

The program which was originally decided upon assumed that a knowledge of flame movement at atmospheric temperature and pressure should be studied first. It was then proposed to determine

(1) The influence of turbulence or movement of the gas at the moment of ignition
(2) The influence of temperature
(3) The influence of pressure or density
(4) The influence of the shape of the explosion chamber
(5) The influence of the position and number of ignition points, together with the importance of the intensity of the ignition

It was assumed that a clear understanding of the above factors as affecting one fuel should be gained before attempting a comparison of the different fuels. To simplify the work a permanent gas, acetylene, was selected for the development of methods of testing and for preliminary experiments. The experiments outlined in this paper represent only a preliminary survey of the factors included in the above outline. It is hoped that future work will give more exact information regarding the effect of these several variables. In addition to the experimental work on flame propagation a comprehensive study of the literature bearing on the subject has been made. Considerable attention is given in this paper to the discussion of the results so found.

After a general survey of the methods of measuring flame propagation which have been used by various investigators, it was decided to use the photographic method chiefly for the reason that, if successful, it would disclose the rate and character of the movement of the flame at any point over the entire exposed distance of travel. To eliminate as many variables as possible in preliminary work a cylinder of constant volume without moving piston was chosen for the explosion chamber.

Naturally many difficulties were encountered in the development of the apparatus. Chief among these were

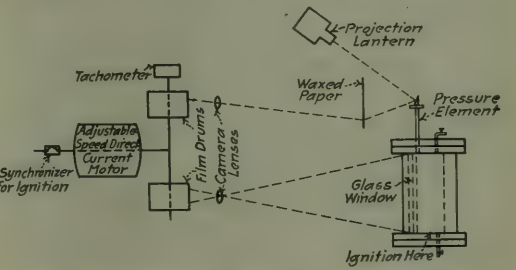


Fig. 1—Arrangement of Apparatus Employed for Measuring Flame Propagation

(*a*) lack of sufficient light from the flame at all times to reproduce itself properly on the film and (*b*) the construction of a gas-tight seal around the window of the explosion cylinder. The apparatus and method at its present stage of development are essentially as follows:

The explosion chamber at the right of the Fig. 1 is a cylinder 4 in. in diameter and 12 in. long, inside measurements, provided with a ¾-in. glass rod extending the entire length as a window. High-pressure needle valves are inserted in the top and bottom of the cylinder for introducing the gas charge and sweeping out the products of combustion. The gas is ignited by a standard spark-plug in the center of the lower end of the cylinder. A Midgley pressure element[3] is inserted in the top of the cylinder, the beam of light from the mirror of the pressure indicator being focused on a wax paper screen and reproduced on a film on the upper of two rotating drums. The light from the flame in the cylinder passes through a camera lens to another film on the lower rotating drum. The two drums are mounted on the same shaft which is driven by an adjustable-speed direct-current motor so that drum speeds of from 100 to 4000 r.p.m. can be obtained. The speed is measured by a combined revolution counter and stop-watch mounted on the end of the shaft. Ignition of the gas charge is synchronized with definite needle points on the film drum through a special sparking device on the

[1]Director, Eastern laboratory, E. I. du Pont de Nemours & Co., Chester, Pa.

[2]Research chemist, Eastern laboratory, E. I. du Pont de Nemours & Co., Chester, Pa.

[3]See The Journal, December, 1920, p. 491.

rear of the driving motor. The apparatus thus gives a direct measurement and comparison of the rates of flame movement and pressure development from a definite ignition point. The fastest film on the market was inadequate for the purpose at hand. It was known from the work of the Bureau of Chemistry that great possibilities lay in the use of the so-called photo-sensitizing dyes for increasing the sensitiveness of emulsion to light of long wave-length. After consultation with the Bureau pinacyanol was selected and used very successfully.

In the course of the development of this apparatus, acetylene-air mixtures were exploded because of the high actinic properties of the flame. During this development

FIG. 2—PHOTOGRAPH OF THE FLAME MOVEMENT IN A MIXTURE COMPOSED OF 10 PER CENT OF ACETYLENE AND 90 PER CENT OF AIR HAVING AN INITIAL TEMPERATURE OF 25 DEG. CENT. (77 DEG. FAHR.), AND A PRESSURE OF 1 ATMOSPHERE

period results were obtained on the nature of the flame movement at atmospheric temperature and pressure and some preliminary experiments carried out on the influence of turbulence, temperature, and pressure. In the experiments on temperature and pressure difficulties were first encountered in attempting to make the cylinder gas-tight around the window. The Midgley pressure element leaked due to the length of time required for charging the cylinder before ignition and was used only to a limited extent. As soon as these difficulties were overcome a few experiments were carried out on the combined influence of high temperature and pressure using ether as a fuel, and on the influence of temperature on the tendency of mixtures of acetylene, oxygen and nitrogen to detonate.

FLAME MOVEMENT AT NORMAL TEMPERATURE AND PRESSURE

Previous investigators of the nature of flame movement at ordinary temperatures and pressures in closed vessels have confined their observations almost entirely to pressure and temperature measurements rather than to flame propagation. Although little information is available concerning the actual flame movements, the rate

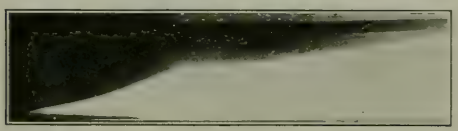


FIG. 3—PHOTOGRAPH OF THE FLAME MOVEMENT IN A MIXTURE COMPOSED OF 20 PER CENT OF ACETYLENE AND 80 PER CENT OF AIR HAVING AN INITIAL TEMPERATURE OF 25 DEG. CENT. (77 DEG. FAHR.) AND A PRESSURE OF 1 ATMOSPHERE

of flame propagation is indicated with fair accuracy by the rate of pressure development within the explosion bomb, and on this basis considerable data have been collected. The point of agreement between the rate of flame propagation and development of pressure accepted by all investigators is that the instant of total inflammation of the gas concurs with the instant of maximum pressures. This fact is substantiated by the experiments of R. V. Wheeler[4] in which close agreement was shown between the rates of flame propagation of various mixtures of methane and air when calculated from actual measurements of the rate of flame movement and from the period required for the development of maximum pressure in two spherical bombs of different capacity.

Early investigators assumed that the instant of ignition coincided with the first appearance of pressure on the indicator or gage. Bairstow and Alexander[5] however have shown that this was not the case, and that after ignition an appreciable period of time elapses before a pressure record can be obtained. Experiments by J. D. Morgan[6] indicate that the inflammation of a gaseous mixture is practically instantaneous with the passage of the igniting spark. It may, therefore, be concluded that the interval of time between ignition and the appearance of pressure is due to a lag in the indicators, or to cooling effect of the base and walls of the vessel. R. V. Wheeler[4] has studied this period using various mixtures of methane and air ignited at the center of spherical bombs and has calculated that approximately one-fifth of the total volume of gas is inflamed before pressure is first recorded.

In our experiments at atmospheric temperature and pressure, mixtures of acetylene and air varying from 5 to 20 per cent of acetylene were exploded in the cylinder and the movement of the flame photographed. A general idea of the velocities of flame movement attained with these mixtures can be obtained from the results given in Table 1.

TABLE 1—VELOCITIES OF FLAME MOVEMENT IN AIR-ACETYLENE MIXTURES

Composition of Mixture		Velocities Attained			
		Maximum		Average	
Acetylene, per cent	Air, per cent	Meters per sec.	Ft. per sec.	Meters per sec.	Ft. per sec.
5	95	9.10	29.86	4.05	13.29
6	94			6.05	19.85
8	92	38.00	124.67	12.50	41.01
10	90	25.00	82.02	15.00	49.21
15	85	20.80	91.86	8.10	26.57
20	80	9.20	36.09	4.00	13.12

As disclosed by previous investigators, the velocity was relatively low for lean and for rich mixtures showing the maximum for the mixtures containing from 8 to 10 per cent of acetylene.

We are not, however, so concerned with the actual velocities of flame movement as we are with the nature of the movement. Typical photographs of the flame movement for the 10 per cent acetylene mixture and for the slow mixture, such as the 20 per cent, are reproduced in Figs. 2 and 3 respectively. In these photographs the film should be considered as moving from right to left and the flame from the bottom to the top. The exceedingly slow initial movement of the flame followed by gradual acceleration is apparent. After the flame has traveled approximately two-thirds the length of the cylinder it suddenly stops. The movement is soon resumed, however, and the flame proceeds slowly to the top of the bomb.

In the case of the 10 per cent mixture there are successions of alternate dark and light vertical bands in the secondary burning period which first become perceptible at the point at which the flame front is arrested. This is also true with the mixtures which gave relatively high velocities. These bands have a slight pitch apparently

[4] See *Journal of the Chemical Society* (England), vol. 113, p. 840.
[5] See *Proceedings of the Royal Society of London*, vol. 76A, p. 340.
[6] See *Engineering*, Oct. 24, 1919, p. 535.

indicating a vibration with the approximate velocity of sound at the temperature. It is notable, however, with mixtures of low velocity, for example, 20 per cent of acetylene, that these vibrations are not present.

One naturally is particularly interested in why the flame comes to rest after traveling a certain distance; also what is responsible for the vibrations exhibited in the relatively fast mixtures. Before offering an explanation of these phenomenon, it is first necessary to consider the rate of pressure development in these experiments as compared with the rate of flame movement.

It will be noted from a comparison of Figs. 4 and 5 that the curves showing the flame movement and the pressure development have the same general form, and that there is an arrest in the pressure development corresponding to the arrest in the flame movement. The time in Fig. 5 is calculated from the point of initial pressure and not from ignition of the charge. Fig. 6, giving the time relations from the ignition of the charge, shows that no

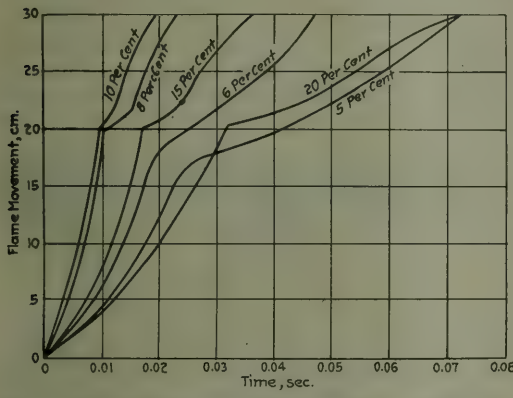


FIG. 4—FLAME MOVEMENT IN MIXTURES CONTAINING VARYING PERCENTAGES OF ACETYLENE

pressure was recorded until the flame had traveled approximately 25 per cent of the length of the bomb. This is in agreement with the findings of previous investigators. It will also be noticed that the arrest in the pressure development occurred at approximately the same time as the arrest in the flame movement. The time of maximum pressure coincides with the time of total inflammation, as had been reported by previous investigators.

Fig. 6 shows also that at the time of the flame and pressure arrests the flame has propagated two-thirds of the length of the bomb whereas only one-quarter of the total pressure has been developed, and that after the arrest the flame in traveling a comparatively short distance produced a very much greater increase in pressure. This is due, it is felt, to the fact that during the burning the expansion of the hot gases behind the flame pushes the flame front forward and compresses the unburned gas ahead of the flame front. Thus, in its propagation the flame is continually entering a gas of higher density which, when burned, naturally produces a greater increment in pressure.

This brings us to a new factor which probably plays a

[1]See *Journal of the Chemical Society* (England), vol. 111, p. 841; vol. 116, p. 573.

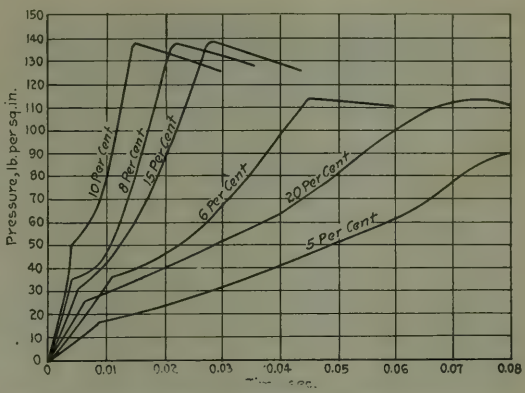


FIG. 5—CURVES OF PRESSURE DEVELOPMENT IN MIXTURES CONTAINING VARYING PERCENTAGES OF ACETYLENE

very important part in determining the rate of flame movement in closed cylinders.

According to Haward and Sastry[1], the rate of flame propagation during the so-called uniform movement period for an 8.9 per cent mixture of acetylene with air is approximately 3.12 meters per sec. (10.24 ft. per sec.). This figure applies to experiments where the influence of pressure behind the flame front did not exist. In our experiments in a closed cylinder mentioned above, an 8 per cent acetylene-air mixture during the uniform movement period attained a velocity of 38 meters per sec. (124.68 ft. per sec.) or 12 times that reported by Haward and Sastry. Apparently the expansion of the hot gases behind the flame front exerted a great effect upon the rate of propagation. It is felt that this factor of expansion of the burned gases is of great importance in the consideration of the flame movement in closed cylinders.

With a realization of the characteristic nature of the pressure development ahead of the flame front and the

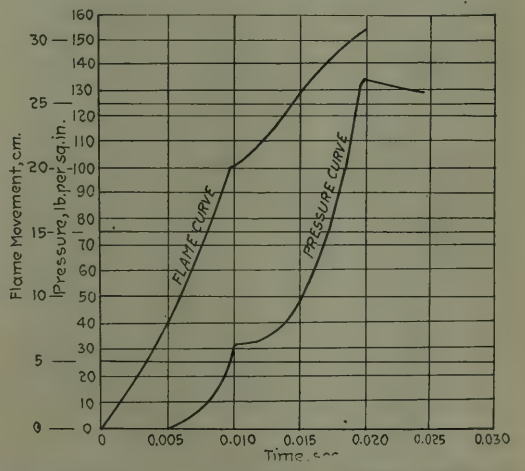


FIG. 6—CURVES OF FLAME MOVEMENT AND PRESSURE DEVELOPMENT IN A MIXTURE COMPOSED OF 10 PER CENT OF ACETYLENE AND 90 PER CENT OF AIR HAVING AN INITIAL TEMPERATURE OF 25 DEG. CENT. (77 DEG. FAHR.) AND A PRESSURE OF 1 ATMOSPHERE

effect of the expanding burned gases it is possible to present an explanation of the flame arrest and the vibrations exhibited by relatively fast burning mixtures. So far as has been determined, Dixon[8] was the first investigator to learn that in a closed tube flame does not travel smoothly through the entire column of gas, and that after traveling for some distance it practically stops as if struck by or striking something. Dixon holds the view that this flame arrest is due to the sound wave which travels from the sparking point at the bottom of the bomb to the top of the bomb, rebounds and strikes the flame front. It is our opinion that these waves are produced by the arrest of the flame rather than being the cause of the arrest. In experiments to be mentioned later, in which turbulence was introduced into the bomb, practically no vibrations were apparent, due, it is felt, to the fact that the turbulence prevented the sharp arrest of the flame movement. Furthermore, it will be noticed in Figs. 2 and 3 that vibrations were present with the 10 per cent gas and absent with the 20 per cent gas, due presumably to the great difference in the sharpness of the arrest. The igniting spark was of the same intensity in all cases. Dixon's own photographs show that vibrations are not present except when there is flame arrest.

It is our theory that it is the high density of the gases ahead of the flame front which arrests the forward movement of the flame. Just why the flame stoppage is sudden rather than a gradual slowing down, as the pressure accumulates ahead of the flame front, is not wholly understood at this time. It is evident that during the entire travel of the flame, the gases approach a state of pressure equilibrium throughout the cylinder and the attainment of this equilibrium is hindered by the fact that the gases are not perfectly elastic. It has been previously shown that the flame front is pushed forward by the expansion of the burned gases and that the unburned gases are compressed to a high density at the same time. Obviously a point can be reached at which the pressure due to the temperature behind the flame is equalled by the pressure due to the density ahead of the flame. At that point the flame front is no longer pushed forward; the propagation is arrested.

Furthermore, when such a point is reached, any burning of gas at the flame front will exert its pressure equally in both directions; that is, ahead and behind the flame front. The arrest in the flame usually occurs after about two-thirds the distance from ignition to the top of the cylinder has been traversed; the volume of the burned gas is then about twice that of the unburned gas. Applying equal pressure to these two unequal volumes obviously causes a greater linear contraction in the larger volume, or the burned gas. A recession of the flame front would be expected under such conditions. In some fast burning mixtures the flame front does recede immediately after the arrest. After the arrest or recession of the flame front, the forward movement is resumed, and a high density again built up ahead of the flame. This cycle of alternate arrest and resumption of the flame movement causes, in our opinion, the vibrations in the burning gases. It is recognized that other factors, such as the temperature and its effect on the elasticity of the gases, and the actual momentum of the forward moving flame, affect the arrest in the flame front. It is felt, however, that high density gas ahead of the flame front is the most important influence.

[8]See *Journal of the Chemical Society* (England), vol. 99, p. 594.
[9]See *Annales des Mines*, Series 8, vol. 4, p. 298.
[10]See *Engineering*, July 11, 1913, p. 61.
[11]See Report of the British Association for the Advancement of Science for 1912, p. 201, and the *Journal of the Chemical Society* (England), vol. 115, p. 181.
[12]See *Journal of the Chemical Society* (England), vol. 119, p. 578.

Influence of Turbulence

The decided increase in the rate of flame propagation due to mechanical agitation of the gaseous mixture was first noted by Schloesing and de Mondesis[9] in 1864, and was described by Mallard and Le Chatelier. This information was apparently forgotten until Clerk and Hopkinson's[10] investigation of 1912. Since that time numerous investigators[11] have studied turbulence, establishing that the speed of burn is increased but the ignition rendered more difficult by agitating the gases.

Some very interesting results have just been published by Mason and Wheeler[12]. A tube 2.15 cm. (0.83 in.) in diameter and 220 cm. (85.53 in.) long was fixed horizontally. Streams of methane and air could be passed at different speeds along the tube, both ends of which were open. The mixtures were ignited electrically at a point 26 cm. (10.24 in.) from one end of the tube and the speeds of the flames were measured by screen wires, the first screen wire being 50 cm. (19.69 in.) from the point of ignition. A mixture containing 6.35 per cent of methane was used and the results given in Table 2 obtained.

TABLE 2.—FLAME SPEEDS IN AIR AND METHANE

Speed of Current of Air and Methane		Speed of Flame	
Cm. per sec.	In. per sec.	Cm. per sec.	In. per sec.
Nil	Nil	287	112.99
23	9.06	582	229.13
43	16.93	952	374.80
75	29.53	1,527	601.18

These results show that a comparatively gentle movement of the mixture as represented by a speed of 23 cm. per sec. (9.06 in. per sec.) nearly doubles the speed of the flame.

In our experiments a study was made of the effect of turbulence at atmospheric temperature and pressure. This study was on 10, 15 and 20 per cent acetylene-air mixtures. Varying degrees of turbulence were obtained by rotating a fan at different speeds, this fan being placed within the bomb at a point approximately equidistant from the two ends. Tests were made first with the fan at rest and then revolving at speeds of 1100, 2200, 3300 and 4400 r.p.m. Typical photographs are shown in Figs. 7 and 8, the former with the fan present but not revolving, and the latter with the fan revolving at 3300 r.p.m. These should be compared with Fig. 2 which was made without the fan being present.

An interesting point to be noted in comparing Figs. 2 and 7 is, that the mere presence of the fan changes the character of the flame arrest. There is a decrease in rate, but this is gradual rather than sudden.

In all of the experiments with the fan revolving, the nature of the flame movement was similar to that shown in Fig 8. It was apparent that although turbulence seemed to interfere with the accumulation of the pressure ahead of the flame front thereby eliminating a sudden arrest and although the distance of smooth accelerated flame travel was increased with increase in turbulence (See Fig. 9), nevertheless the flame movement did slow down in all cases as it approached the top of the bomb. It is recognized, however, that still greater turbulence than obtained in our experiments, or other types of gas agita-

tion than that used, might have given continually accelerating rates of propagation through the entire column of gas.

An idea of the effect of turbulence on the actual speed of the flame movement is given in Table 3. These results show that the slower the rate of propagation in the mixture without turbulence, the greater the effect of turbulence on that rate.

TABLE 3—INFLUENCE OF TURBULENCE ON THE VELOCITY OF FLAME MOVEMENT IN ACETYLENE-AIR MIXTURES

Acetylene, per cent / Air, per cent	Composition of Mixture: 10 / 90		15 / 85		20 / 80	
Speed of Fan, r. p. m.	Average Velocity: Meters per sec.	Ft. per sec.	Meters per sec.	Ft. per sec.	Meters per sec.	Ft. per sec.
At Rest	15.0	49.21	8.1	26.57	4.0	13.12
1,100	21.3	69.88	17.5	57.41	6.9	22.64
2,200	25.0	82.02	19.8	64.96	10.7	35.11
3,350	29.6	97.11	24.5	80.38	14.9	48.88
4,400	38.9	127.62	30.4	99.74	20.6	67.63

Although the results obtained to date are of a preliminary nature, they indicate the tremendous influence of turbulence on the rate of flame propagation and the important relation which a complete knowledge of the nature and direction of the flow of gases bears to the design of internal-combustion engines.

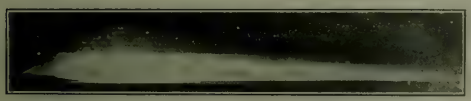


FIG. 7—PHOTOGRAPH OF FLAME MOVEMENT IN A MIXTURE COMPOSED OF 10 PER CENT OF ACETYLENE AND 90 PER CENT OF AIR HAVING AN INITIAL TEMPERATURE OF 25 DEG. CENT. (77 DEG. FAHR.) AND A PRESSURE OF 1 ATMOSPHERE

When This Photograph Was Taken the Fan Which Was Placed within the Bomb to Produce Turbulence Was Not Rotating. This Illustration Should Be Compared with Fig. 2 on Page 210, Which Was Taken Before the Fan Was Placed in the Bomb

INFLUENCE OF TEMPERATURE AND PRESSURE ON PROPAGATION

Several investigators have made statements which indicate that increased initial temperatures increase the rate of flame propagation and it seems entirely reasonable to expect such behavior. However, the study of temperature effect has been greatly neglected in the past and few actual experimental data are available. Our work on increased temperature at constant pressure was carried out on mixtures varying from 8 to 20 per cent of acetylene in air at temperatures from 25 to 125 deg. cent. (77 to 257 deg. fahr.). With a 10 per cent acetylene-air mixture at 25 deg. cent. (77 deg. fahr.) an average velocity of 15 meters per sec. (49.21 ft. per sec.) was obtained; at 50 deg. cent. (122 deg. fahr.), 12.2 meters per sec. (40.03 ft. per sec.); at 70 deg. cent. (158 deg. fahr.), 10.8 meters per sec. (35.43 ft. per sec.); and at 80 deg. cent. (176 deg. fahr.), 10.35 meters per sec. (33.96 ft. per sec.). The maximum velocity attained was practically unchanged over this range of temperature. With richer mixtures containing 15 and 20 per cent acetylene there was an apparent increase in rate of propagation with increase of temperature from 25 to 75 deg. cent. (77 to 167 deg. fahr.), and then a decrease in rate

[13]See the Gas Petrol and Oil Engine by Dugald Clerk, vol. 1, p. 166.

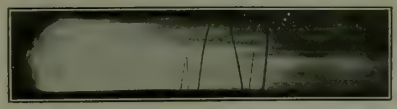


FIG. 8—FLAME MOVEMENT IN A MIXTURE COMPOSED OF 10 PER CENT OF ACETYLENE AND 90 PER CENT OF AIR HAVING AN INITIAL TEMPERATURE OF 25 DEG. CENT. (77 DEG. FAHR.) AND A PRESSURE OF 1 ATMOSPHERE

When This Photograph Was Taken the Fan Which Was Placed in the Bomb to Produce Turbulence Was Revolving at 3300 R.P.M.

on further rise to 125 deg. cent. (257 deg. fahr.). Difficulty was encountered in obtaining pictures at the higher temperatures, as the lowered density of the gas greatly diminished the available amount of light. It is possible that this decrease in density of the gas by dispersion may have counteracted any increase in rate of propagation due to increase in initial temperature. The results obtained indicated that increased temperature produced little effect upon the rate of flame propagation. The investigation was not carried over a sufficiently wide range of conditions to warrant a final conclusion, however.

The effect of initial pressure on the rate of flame propagation may be more easily studied than that of initial temperature, for pressure variations may be made independent of temperature changes. The results available are, therefore, more definite. Very high initial pressure apparently produces no material increase in the rate of flame propagation. This is brought out by the work of Peteval described by Dugald Clerk.[13] In his experiments Peteval measured the rate of pressure development and, therefore indirectly, the rate of flame propagation of a mixture of coal gas and air compressed to an initial pressure of 1100 lb. per sq. in. It was found that the time required to attain maximum pressure was almost identical with that required by the same mixture when fired at atmospheric pressure.

In our attempts to study the effect of pressure on the rate of flame propagation, considerable difficulty was en-

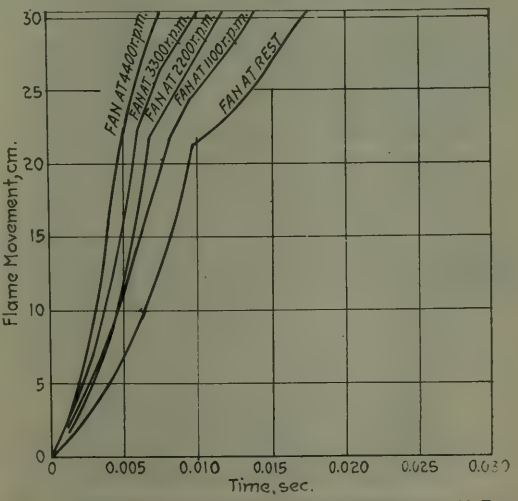


FIG. 9—TURBULENCE EFFECTS ON A MIXTURE COMPOSED OF 10 PER CENT OF ACETYLENE AND 90 PER CENT OF AIR HAVING AN INITIAL TEMPERATURE OF 25 DEG. CENT. (77 DEG. FAHR.) AND A PRESSURE OF 1 ATMOSPHERE PRODUCED BY ROTATING THE PRESSURE FAN AT VARIOUS SPEEDS

FIG. 10—TYPICAL PHOTOGRAPH OF A DETONATION OBTAINED IN A MIXTURE CONSISTING OF 20 PER CENT OF ACETYLENE, 29.6 PER CENT OF OXYGEN AND 50.4 PER CENT OF NITROGEN HAVING AN INITIAL TEMPERATURE OF 25 DEG. CENT. (77 DEG. FAHR.) AND A PRESSURE OF 1 ATMOSPHERE

countered in keeping the bomb gas-tight, and the results cannot be presented as conclusive evidence at this time. The results obtained on various mixtures of acetylene and air under initial pressures of from one to four atmospheres, indicated that with each gas mixture the rate of propagation increases with an increase in the initial pressure up to a critical density and that with any further increase in the pressure above that critical value no increase in the rate of propagation is obtained. The critical density in most cases is two to three atmospheres. Similar results, described below, are reported by Dixon on the effect of pressure on the velocity of the detonation

FIG. 11—PHOTOGRAPH OF A MIXTURE OF 20 PER CENT OF ACETYLENE, 32 PER CENT OF OXYGEN AND 48 PER CENT OF NITROGEN SHOWING THE OCCURRENCE OF DETONATION JUST BEFORE THE FLAME REACHED THE TOP OF THE BOMB
The Mixture in This Case Had an Initial Temperature of 25 Deg. Cent. (77 Deg. Fahr.) and Was Subjected to a Pressure of 1 Atmosphere

wave. A consideration of the information at hand indicates that increased initial pressure does not materially affect the rate of flame propagation. It must be understood, of course, that these statements apply only to the effect of temperature and pressure on the rate of propagation during any particular phase of flame travel; for it is well known that the inflammability of any mixture and the nature of the propagation of the flame through a mixture is greatly influenced by any increase in the temperature and the pressure.

If our assumptions that temperature and pressure do not materially affect the rate of flame propagation are correct, then consideration must be given to the effect of these factors on the nature of the propagation to find an explanation for certain phenomena which occur in an internal-combustion engine and which are known to be associated closely with the pressure and temperature conditions existing in the engine. The normal propagation of the flame through the combustion-chamber might be influenced in various ways, as for example, by the development of the detonation wave or by the appearance of autoignition in the unburned gases ahead of the flame front.

In a study of fixed gases such as acetylene, hydrogen, carbon bisulphide and cyanogen, Dixon[14] has established that a considerable distance of flame travel from ignition is necessary before the development of a detonation wave, and that this necessary distance depends upon the fuel, and upon the ratio of fuel to oxygen. For example, the acetylene burn accelerates to detonation in a much shorter distance than does that of hydrogen. Dixon[15] has recently disclosed that he has been studying the development of the detonation wave in mixtures of liquid fuels, such as ether, alcohol, pentane and benzine, in air. No details of the work are given, but ether and alcohol are classed together as able to just propagate detonation, and benzine and pentane are classed together as unable to accelerate to detonation at atmospheric temperature and pressure.

It has been found that the velocity of the detonation wave is decreased by increase in temperature[16] from 25 to 100 deg. cent. (77 to 212 deg. fahr.). A study of both reduced and increased initial pressures has shown that for each gas mixture a critical pressure exists, usually two or three atmospheres absolute, below which the detonation velocity increases with any increase in the pressure, but above which the velocity is practically constant and independent of any pressure increase.

A search of the literature, however, reveals no definite information concerning the influence of various physical factors, such as temperature and pressure, on the development of detonation in the case of any particular fuel-air mixture.

Our work was therefore confined to the identification of the detonation wave as determined by our apparatus and a brief study of the effect of the composition of the mixture of acetylene, oxygen and nitrogen, and of the influence of an increased initial temperature and pressure, on the tendency to develop detonation. An attempt was also made to develop detonation in the case of a badly knocking fuel such as ether, by igniting at a high temperature and pressure. No detonation was obtained in this case and the results are therefore discussed under the subject of autoignition below.

Preliminary work on acetylene-air mixtures showed that the detonation wave could not be set up in the 12-in. cylinder by igniting at atmospheric temperature and pressure. The mixtures were therefore enriched with oxygen. Fig. 10 is a typical photograph of a detonation finally obtained in a mixture containing 20 per cent of acetylene, 29.6 per cent of oxygen, and 50.4 per cent of nitrogen. It may be seen that the flame progresses with an accelerated velocity to a point about 7 in. from ignition at which it attains a very high and apparently uniform rate of travel. This is undoubtedly detonation though no attempt was made to determine the actual detonation velocity.

Fig. 11 which is reproduced from a photograph of a mixture of 20 per cent of acetylene, 32 per cent of oxygen and 48 per cent of nitrogen, shows detonation occurring just before the flame reached the top of the bomb. It is interesting to note that a slight change in the composition of the gas mixture exerts a great influence on the tendency to detonate or on the distance traveled by the flame before detonation was set up.

In studying the effect of the composition of mixtures of acetylene, oxygen and nitrogen on their tendency to detonate, four series of mixtures containing respectively 10, 12, 15 and 20 per cent of acetylene were selected.

[14] See the *Philosophical Transactions of the Royal Society of London*, vol. 200, p. 315.
[15] See THE JOURNAL, December, 1920, p. 521.
[16] See Report of the Bakerian Lecture delivered by Herold B. Dixon, published in the *Philosophical Transactions of the Royal Society of London* for 1893.

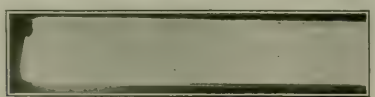


FIG. 12—PHOTOGRAPH SHOWING AUTOIGNITION IN A MIXTURE CONTAINING 15 PER CENT OF ACETYLENE, 41 PER CENT OF OXYGEN AND 44 PER CENT OF NITROGEN HAVING AN INITIAL TEMPERATURE OF 25 DEG. CENT. (77 DEG. FAHR.) AND A PRESSURE OF 1 ATMOSPHERE

Amounts of oxygen ranging from less than the amount required to burn the acetylene to carbon monoxide to an excess of the amount required for combustion to carbon dioxide were used in each series. Photographs of the explosions of these various mixtures showed that detonation had been set up in only one case, that of the mixture containing 20 per cent of acetylene and oxygen in the combining proportion to give carbon monoxide. However, it must be pointed out that although detonation was obtained in only one instance, autoignition in the unburned gases ahead of the flame front was exhibited over a wide range of mixtures. Fig. 12 is a typical example of this phenomenon as shown by a mixture containing 15 per cent of acetylene, 41 per cent of oxygen and 44 per cent of nitrogen.

These results have indicated, to our mind, certain rather obvious conclusions, namely

(1) Detonation is most easily initiated in a mixture containing acetylene and oxygen in the combining proportion to give carbon monoxide

(2) The initiation of the detonating wave is delayed by the presence of an inert gas such as nitrogen. Mixtures containing acetylene and oxygen in the proportion given under (1) and more than approximately 50 per cent of nitrogen will not detonate in a 12-in. space at atmospheric pressure and temperature when ignited with a spark of normal intensity

(3) Oxygen in excess of the proportion given under (1) acts as inert gas and retards the initiation of detonation

Although these statements apply directly only to the behavior of acetylene mixtures, the work of other investigators on numerous gases has shown that the presence of inert gases in combustible mixtures inhibits detonation to a marked extent.

The effect of temperature on the tendency of acetylene mixtures to detonate was investigated by firing a series first at atmospheric pressure and temperature, and then at an initial temperature of 125 deg. cent. (257 deg. fahr.) and 10-lb. gage pressure. Figs. 13 to 17, inclusive, present the comparative records obtained with four mixtures fired under these conditions. It is evident that in every case in which the initial temperature of the mixture was raised, the detonation occurs later. It is impossible to state definitely from so few results that an increased initial temperature actually delays the setting up of detonation in a given mixture. However, it is our belief that high initial temperature does not accelerate the initiation of the detonating wave as has recently been suggested.

Autoignition

It is well known that fuel-air mixtures ignite and burn when subjected to compression sufficient to raise the temperature of the mixture to or above its ignition point. As pointed out above, the movement of the flame from ignition compresses the unburned gases ahead of the flame front. This increase in the density of the unburned gases is, of course, accompanied by an increase in the temperature and it is reasonable to assume that these gases could thus be ignited. The behavior of gas mixtures under high compression and the resulting flame movements are therefore of importance.

Dixon[17] has presented the most interesting results on the behavior of gas mixtures at high pressures in an investigation carried out primarily for the purpose of determining the ignition points of gaseous mixtures. Our particular interest is centered on the nature of the movement of the flame in gases ignited under the high temperature and pressure employed. In these experiments the various gas mixtures were compressed by driving a piston into a tube by means of a falling pendulum, thus obtaining extreme conditions of temperature and pressure almost instantaneously. With a mixture of carbon bisulphide and oxygen in the proportion of 1 to 5 the mixture ignited through autoignition. Relatively low velocities of flame movement were obtained even under the highest compressions, and there was no evidence of detonation. An idea of the severity of the tests to which Dixon subjected these explosive mixtures, and the nature of the flame movement, is given in Table 4.

Commenting on the results with carbon bisulphide, Dixon says,

> The flame took an appreciable time to spread through the space occupied by the gas, and in no instance did the

Fig. 13—Results Obtained with a Mixture Consisting of 20 Per Cent of Acetylene, 30 Per Cent of Oxygen and 50 Per Cent of Nitrogen

In the View at the Left the Initial Temperature Was 25 Deg. Cent. (77 Deg. Fahr.) and the Pressure Was 15 Lb. Absolute. In the Other View the Initial Temperature Was Raised to 125 Deg. Cent. (257 Deg. Fahr.) and the Pressure to 25 Lb. Absolute, with the Result That Detonation Was Delayed

Fig. 14—Results Obtained with a Mixture Consisting of 22.50 Per Cent of Acetylene, 33.75 Per Cent of Oxygen and 43.75 Per Cent of Nitrogen

In the View at the Left the Initial Temperature Was 25 Deg. Cent. (77 Deg. Fahr.) and the Pressure 15 Lb. Absolute. In the Other View the Initial Temperature Was 125 Deg. Cent. (257 Deg. Fahr.) and the Pressure Was 25 Lb. Absolute

Fig. 15—Results Obtained with a Mixture of 25 Per Cent of Acetylene, 37.5 Per Cent of Oxygen and 37.5 Per Cent of Nitrogen

In the View at the Left the Initial Temperature Was 25 Deg. Cent. (77 Deg. Fahr.) and the Pressure 15 Lb. Absolute. In the Other View the Initial Temperature Was 125 Deg. Cent. (257 Deg. Fahr.) and the Pressure Was 25 Lb. Absolute

Fig. 16—Results Obtained with a Mixture of 27.50 Per Cent of Acetylene, 41.25 Per Cent of Oxygen and 31.25 Per Cent of Nitrogen

In the View at the Left the Initial Temperature Was 25 Deg. Cent. (77 Deg. Fahr.) and the Pressure 15 Lb. Absolute. In the Other View the Initial Temperature Was 125 Deg. Cent. (257 Deg. Fahr.) and the Pressure Was 25 Lb. Absolute

Fig. 17—Results Obtained with a Mixture of 30 Per Cent of Acetylene, 45 Per Cent of Oxygen and 25 Per Cent of Nitrogen

In the View at the Left the Initial Temperature Was 25 Deg. Cent. (77 Deg. Fahr.) and the Pressure 15 Lb. Absolute. In the Other View the Initial Temperature Was 125 Deg. Cent. (257 Deg. Fahr.) and the Pressure Was 25 Lb. Absolute

[17]See *Journal of the Chemical Society* (England), vol. 99, p. 588 and vol. 105, p. 2027.

TABLE 4—BEHAVIOR OF MIXTURES OF CARBON BISULPHIDE AND OXYGEN IN THE PROPORTION OF 1 TO 5 AT HIGH COMPRESSION IN A TUBE 12 MM. (0.048 IN.) IN DIAMETER AND 650 MM. (25.59 IN.) LONG

Compression Ratio	Calculated Pressure, Atmospheres	Calculated Temperature		Nature of Flame Movement
		Deg. Cent.	Deg. Fahr.	
1 to 7.3	15.30	335	635	Autoignition near end of tube, no detonation.
1 to 9.4	21.55	394	723	Autoignition near end of tube, no detonation.
1 to 10.5	25.06	422	792	Autoignition near end of tube, no detonation.
1 to 10.5[18]	25.06	422	792	Velocity of 14 meters per sec. (16.40 ft. per sec.)
1 to 10.5[19]	25.06	422	792	Velocity of 60 meters per sec. (196.85 ft. per sec.)

[18]Slow compression.
[19]Fast compression.

flame travel through the tube with a velocity approaching that of detonation. In the fastest instance observed, the flame traveled 25 mm. (0.984 in.) in 0.00025 sec., that is, at 100 meters per sec. (328.08 ft. per sec.), whereas the explosion wave (detonation) travels in this mixture at a rate of nearly 1800 meters per sec. (1.12 miles per sec.).

Further results from the same work of Dixon on mixtures of hydrogen and oxygen, indicated that autoignition took place and that detonation may have developed later in some cases. Results obtained with a mixture of hydrogen and oxygen in the proportion of 1 to 3 are given in Table 5.

In commenting on results obtained with hydrogen-oxygen mixtures in the proportion of 2 to 1 a mixture having a very high detonation velocity of 2800 meters per sec. (1.74 miles per sec.), Dixon says

> When electrolytic gas was fired by compression the spread of the flame was far more rapid than that with excess oxygen; but in no case was the gas detonated instantaneously, even when the fall of the pendulum was unchecked except by the explosion itself.

In these experiments the flame was moving through a gas which was not only at a high density but also at a high temperature, in the one case, approximately 975 deg. cent. (1787 deg. fahr.). In spite of these very high temperatures, the dilute mixtures of carbon bisulphide and oxygen and of hydrogen and oxygen showed low rates of flame movement as compared with what one would expect under these conditions.

It would be expected that when a gas is compressed to a temperature far above its ignition point, every particle of the inflammable gas would essentially either be oxidized or decomposed instantaneously. Dixon has shown, however, that this is not necessarily the case, but that the ignition starts at a point and proceeds slowly with a gradual acceleration, the actual velocity attained depending to a large extent on the point at which ignition started. For example, in his experiments the maximum velocities attained appear to be comparatively low when the autoignition started near the center of the tube, whereas relatively high velocities were attained when the autoignition started near one end of the tube and had the full length of the tube to travel.

The above results from Dixon's early work are, of course, on gases whose behavior may not be representative of that of the fuels used in internal-combustion engines. In Dixon's abstract of results recently presented in England which appeared in THE JOURNAL for December, 1920, he discloses that he has been studying the behavior under compression of such fuels as pentane, hexane, benzine, alcohol and ether. The details of these results are awaited with keen interest.

As stated above, in our work on the influence of increased temperature and pressure on the nature of flame propagation a study was made of a badly knocking fuel, namely ether. Mixtures containing approximately from 6 to 8 per cent of ether were ignited at 150 to 160 deg. cent. (302 to 320 deg. fahr.) initial temperature and pressures of from 65 to 75 lb. absolute. Fig. 18 is a typical example of the characteristic flame record obtained. It may be seen that the flame progressed from ignition at a slowly accelerated rate, until it was arrested a short distance beyond the center of the cylinder. At the time of the arrest autoignition appeared in the unburned gas at a point about equidistant between the advancing flame front and the top of the bomb. Flame spread from this center of autoignition toward both the top of the bomb and the original flame front, causing in

TABLE 5—BEHAVIOR OF A MIXTURE OF HYDROGEN AND OXYGEN IN THE PROPORTION OF 1 TO 3 AT HIGH COMPRESSION

Compression Ratio	Length of Column of Gas at Moment of Firing		Calculated Pressure, Atmospheres	Calculated Temperature		Behavior of Gas
	Cm.	In.		Deg. Cent.	Deg. Fahr.	
1 to 15.0	3.6	1.42	44.3	550 to 578	1022 to 1072	Autoignition near middle of tube. Detonation may have developed.
1 to 18.0	3.0	1.18	57.2	640	1184	Autoignition near end of tube. Burned slowly.
1 to 27.0	2.0	0.79	100.9	810	1490	Autoignition near end of tube. Burned slowly.
1 to 41.5	1.3	0.51	184.5	975	1787	Autoignition near end of tube. Detonation may have developed.

the latter case a decided recession of the original flame front. In some cases, after total inflammation had been accomplished, vibrating compression waves were set up

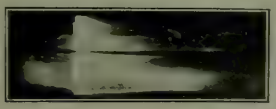


FIG. 18—A TYPICAL EXAMPLE OF FLAME MOVEMENT IN A MIXTURE CONSISTING OF APPROXIMATELY 8 PER CENT OF SULPHURIC ETHER AND 92 PER CENT OF AIR HAVING AN INITIAL TEMPERATURE OF 160 DEG. CENT. (320 DEG. FAHR.) AND A PRESSURE OF 65 LB. ABSOLUTE

in the burned gases similar to those described earlier in this paper.

The most important part of our work with ether-air mixtures was the recording of the pressure development during explosions in which the phenomenon of autoignition took place. Fig. 19 gives the flame and pressure records of an explosion of an ether-air mixture at 150 deg. cent. (302 deg. fahr.) and 65 lb. absolute pressure. In this explosion autoignition appeared but no vibrations occurred in the after-burning. It may be noted that the development of pressure was slow until autoignition appeared. Then the pressure increased with great rapidity.

Fig. 20 gives the records of an ether-air mixture at 150 deg. cent. (302 deg. fahr.) and 75 lb. absolute pressure. Here again autoignition of the high-density gas ahead of the flame front was evident and in this case distinct vibrations were recorded. The records of this explosion are more clearly shown in Fig. 21, in which the flame and pressure curves have been plotted to the

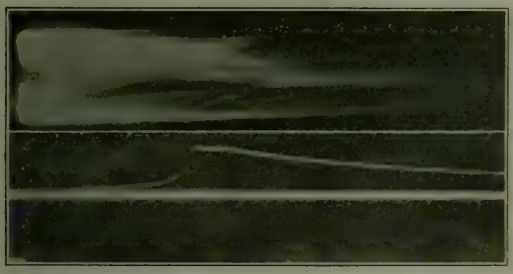


FIG. 19—THE FLAME (UPPER) AND THE PRESSURE (LOWER) RECORD OF AN EXPLOSION OF AN ETHER-AIR MIXTURE AT A TEMPERATURE OF 150 DEG. CENT. (302 DEG. FAHR.) AND A PRESSURE OF 65 LB. ABSOLUTE

same time scale. From this it can be seen that the first appearance of pressure occurred after the flame had traveled approximately one-third of the distance to the top of the cylinder, and that the pressure was thereafter developed slowly until the time at which autoignition occurred. In fact the flame had traveled nearly two-thirds the length of the bomb and a pressure of only 115 lb. per sq. in. had been developed in 0.036 sec. With the appearance of autoignition in the high-density gas pressure developed very rapidly, 425 lb. per sq. in. being recorded in 0.006 sec. The instant of maximum pressure was found to coincide with the instant of total inflammation of the bomb. Upon the attainment of maximum pressure rapid vibrations of the Midgley pressure indicator were recorded. The period of these vibrations has been carefully determined and found to agree exactly with that of the vibrating compression waves in the after-burning as recorded in the flame photograph. In our opinion the pressure record obtained in this explosion appears similar to that shown by the Midgley indicator while ether is knocking in an engine.

THE NATURE OF THE FUEL KNOCK

Of the many theories which have been presented on the nature of the "fuel knock," that of the detonation of the fuel-air mixture in the engine cylinder has recently received considerable credence, and it is certain that if detonation can be set up in the combustion-chamber of an

FIG. 20—THE FLAME (UPPER) AND THE PRESSURE (LOWER) RECORD OF AN EXPLOSION OF AN ETHER-AIR MIXTURE AT A TEMPERATURE OF 150 DEG. CENT. (302 DEG. FAHR.) AND A PRESSURE OF 75 LB. ABSOLUTE

engine the phenomenon of knocking would be satisfactorily explained. However, it has been our experience to date that detonation is set up only with great difficulty in a closed cylinder of small dimensions.

On the other hand, autoignition of the high-density gases ahead of the flame front occurs over a wide range of fuel mixtures and conditions and gives a sudden development of pressure similar, in our opinion, to that characteristic of a knocking explosion. It is possible that this autoignition may set up detonation in some cases, thereby acting as an intermediate stage in knocking. Our experiments have not been carried to a definite conclusion, and present data do not warrant presentation of autoignition as a positive explanation for knocking. It is our feeling, however, that information at hand favors more strongly the theory of autoignition of the

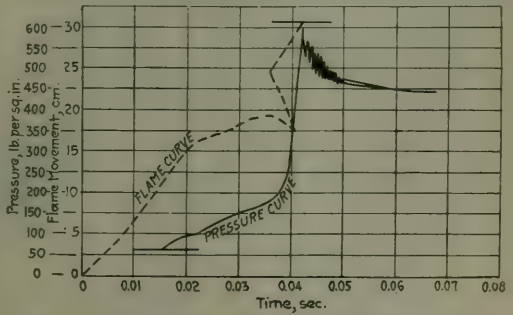


FIG. 21—FLAME AND PRESSURE RECORD OF THE ETHER-AIR MIXTURE AT A TEMPERATURE OF 150 DEG. CENT. (302 DEG. FAHR.) AND AN ABSOLUTE PRESSURE OF 75 LB.

high-density gases ahead of the flame front than that of detonation.

The following four characteristics of the fuel knock have been generally recognized: (*a*) high initial temperature and (*b*) high initial pressure favor knocking; (*c*) the tendency to knock increases with decrease in volatility in comparing the members of the same homologous series and (*d*) volatility and knocking have no relation when different homologous series are compared.

Autoignition of the gas ahead of the flame front is likewise favored by a high initial temperature or pressure of the gas charge. The only results available on the effect of increased temperature on the tendency to detonate, indicate that high temperature inhibits detonation. Moore[20] shows that in the same homologous series the autoignition point becomes lower as the boiling point rises. With decrease in volatility of the members of a series their tendency to autoignite and knock are increased. There are no data at hand to show the relation of the tendency to detonate with the volatility of a given series of compounds.

The many determinations of autoignition points reported in the literature on the subject show conclusively that no relation exists between the volatility and the autoignition point when the comparison is extended to various series of compounds. The information on the tendency of liquid fuels to detonate is meagre. As stated above, Dixon classes ether and alcohol together in their tendency to detonate, and states that pentane and benzine do not accelerate to detonation at atmospheric temperature and pressure. Our attempts to obtain detonation with ether at high temperature and pressure in a 12-in. cylinder were failures. These results are not consistent with the order of the fuels to knock[21]; the tendency being, respectively, ether, pentane, benzine and alcohol.

It should be emphasized also that there is a certain necessary distance of flame travel from ignition to the point at which detonation is set up, and that the distance is increased by the presence of dilutent gases, even excess oxygen. In the engine the explosion chamber is of very small dimensions and the atmosphere is air diluted with from 10 to 25 per cent of the products of combustion. The possibility of detonation under such conditions appears exceedingly remote.

SUMMARY

(1) Apparatus and methods of study have been developed with which the rate and nature of the flame movement and pressure development in gaseous explosions can be recorded under conditions approximating those of the internal combustion engine

(2) It has been shown that in the case of acetylene-air mixtures ignited at atmospheric temperature and pressure the maximum velocity of flame movement is obtained with that mixture corresponding closely to the theoretical proportion for the formation of carbon monoxide

(3) It has been substantiated that first record of pressure development occurs after an appreciable distance of flame travel, and that the instant of maximum pressure development coincides with that of total inflammation of the gas charge

(4) A theory has been presented that the arrest occurring in mixtures fired without turbulence, and the consequent vibrations noted in the burning gases, are due essentially to the high density developed in the gases ahead of the flame front

(5) It has been confirmed that turbulence greatly accelerates flame propagation, and it has been shown that turbulence changes the character of the flame travel by the elimination of the sudden arrest and vibratory movement

(6) Within the limits of the experiments carried out it was found that increased temperature and pressure have little effect upon the rate of flame propagation

(7) The initiation of a detonation has been found possible at atmospheric conditions and in a closed cylinder of 12-in. length only by the use of relatively high concentrations of acetylene and a thorough enrichment of the atmosphere with oxygen

(8) Preliminary results have been presented which indicate that high temperature inhibits the initiation of the detonation

(9) It has been shown that autoignition of the high-density gases ahead of the flame front occurs over a wide range of mixtures and conditions and that it is especially favored by high temperature and pressure

(10) A record of pressure development in an explosion of an ether-air mixture in which autoignition occurred in the high-density gases ahead of the flame has been obtained; this record, in our opinion, is similar to that of a knocking explosion of ether

(11) A theory has been advanced that autoignition of the high-density gases ahead of the flame front is accountable for the fuel knock

[20] See *Journal of the Society of Chemical Industry*, vol. 36, p. 109.
[21] See THE JOURNAL, August, 1920, p. 123.

Standardization of Petroleum Specifications

THE Government Committee on Standardization of Petroleum Specifications has recently issued a bulletin[1] setting forth the specifications which must be met by all petroleum products sold to Government agencies after Dec. 29, 1920. The Committee on Standardization of Petroleum Specifications, created by an order of the President issued July 31, 1918, is charged with the "duty of preparing and adopting specifications for the supply of petroleum and its products to any and all departments, bureaus, agencies and offices of the Government" under the direction of the United States Fuel Administrator.

Certain of the specifications drafted by the Committee are universally applied by petroleum refiners in the production of gasoline and lubricants sold to the owners of automotive apparatus. The Committee appreciating this fact consults with representatives of the automotive and petroleum industries when revisions and additions are made and this practice insures the drafting of specifications which are generally acceptable to private consumers as well as the Government. On Dec. 23, some of the technical advisers to the Committee met with the Lubricants Division of the Standards Committee and discussed the present specifications as they had drafted them for use in 1921. The discussion brought out the fact that the Government Committee was anxious to cooperate with the industry and suggested that the specifications affecting automotive apparatus be widely circulated and constructive criticism submitted to the Committee for its consideration. For this reason an abstract of the recent bulletin is published herewith for the information of our members.

Methods of Testing

The bulletin describes in considerable detail the prescribed methods of conducting the tests which must be made under the specifications. These will not be reprinted here because of their comprehensive character. The report itself should be consulted by those particularly interested in the testing methods and apparatus. In general, the Committee has adopted the methods recommended by the American Society for Testing Materials, as these methods agree with those used by Government agencies and also have the sanction of a number of petroleum trade associations.

Methods of applying the "doctor" test to gasoline are given as well as the procedure and apparatus for determining the distillation characteristics of a particular sample. Methods for checking the flash and fire points of lubricating oils are described in detail with the prescribed methods of measuring viscosity. The pour test, tests for carbon residue and acidity, method of determining emulsification and demulsibility are all fully outlined so that the application of the specifications will be uniform and all results comparative.

The Committee recognizes the fact that the tests specified for lubricating oils may not necessarily determine their effectiveness as lubricants but it is felt that the practical application of the specifications as drawn will at least prevent the purchase of the poorer oils and offer an opportunity to study further the properties of oils which guarantee efficient lubrication.

Gasoline and Kerosene

Three grades of gasoline are covered by the specifications; motor gasoline, for use as a fuel in automobile, motorboat and similar engines; aviation gasoline, fighting grade, for use as a fuel in engines of fighting planes where the highest efficiency is required; and aviation gasoline, domestic grade, for aviation engine fuel where the fighting grade is not required. For convenience in making comparisons these three specifications are given in Table 1.

TABLE 1—COMPARATIVE CHART OF GASOLINE SPECIFICATIONS

Grade[2]	Commercial Gasoline	Aviation Gasoline, Domestic Grade	Aviation Gasoline, Fighting Grade
Color	White	Water White	Water White[3]
Doctor Test shall be negative	Not specified	Applies	Applies
Corrosion Test; 100 cc. of the gasoline shall cause no gray or black corrosion and no weighable amount of deposit when evaporated in a polished copper dish	Not specified	Applies	Applies
Unsaturated Hydrocarbons; maximum proportion of the gasoline soluble in concentrated sulphuric acid, per cent	Not specified	E	1
Acid Heat Test; The gasoline shall not increase in temperature more than 10 deg. fahr.	Not specified	Applies	Applies
Thermometer reading when first drop is recovered in receiver not more than	140 deg. fahr.		
Thermometer reading when 5 per cent is recovered in receiver		122 to 167 deg. fahr.	122 to 149 deg. fahr.
Thermometer reading when 20 per cent is recovered in receiver not more than	221 deg. fahr.		
Thermometer reading when 50 per cent is recovered in receiver not more than	284 deg. fahr.	221 deg. fahr.	203 deg. fahr.
Thermometer reading when 90 per cent is recovered in receiver not more than	374 deg. fahr.	311 deg. fahr.	257 deg. fahr.
Thermometer reading when 96 per cent is recovered in receiver not more than		347 deg. fahr.	302 deg. fahr.
End-point shall not be higher than	437 deg. fahr.	374 deg. fahr.	329 deg. fahr.
Distillate recovered in the receiver from the distillation at least	95 per cent	96 per cent	96 per cent
When the residue is cooled and added to the distillate in the receiver the distillation loss shall not exceed		2 per cent	2 per cent
Acidity: The residue after distillation shall not show an acid reaction		Applies	Applies

[2]Each grade of gasoline shall be free from undissolved water and suspended matter.
[3]The War Department requires the fighting grade to be colored red after inspection and acceptance.

Two grades of kerosene are covered, one for illuminating purposes, the other as a fuel. The specification for fuel kerosene follows:

Prime White Kerosene

This specification covers the grade of kerosene used where kerosene is required primarily as a fuel and for cleaning purposes. This oil can be used as an illuminant in case of necessity.

The oil shall be free from water, glue, and suspended matter.

Color: The color shall not be darker than No. 16 Saybolt.

Flash point: The flash point shall not be lower than 115 deg. fahr. (Tag closed tester)

Sulphur: The sulphur shall not be more than 0.09 per cent.

Floc: The floc test shall be negative.

Distillation: The end point shall not be higher than 625 deg. fahr.

Cloud test: The oil shall not show a cloud at 5 deg. fahr.

Burning test: The oil shall burn freely and steadily for 8 hr.

[1]Report of Committee on Standardization of Petroleum Specifications printed in Bulletin No. 5 of the Bureau of Mines. Copies of the bulletin can be secured without charge by addressing the Director, Bureau of Mines, Washington.

Fuel Oil for Diesel Engines

Fuel oil intended for use in Diesel engines must pass the following specification.

This specification covers the grade of oil used as a fuel for Diesel engines.

Fuel oil shall be a hydrocarbon oil, free from grit, acid and fibrous or other foreign matters likely to clog or injure the burners or valves. If required, it shall be strained by being drawn through filters of wire gauze of 16 meshes to the inch. The clearance through the strainer shall be at least twice the area of the suction pipe, and the strainers shall be in duplicate.

Flash point: The flash point shall not be lower than 150 deg. fahr. (Pennsky-Martens closed tester)

Water and sediment: Water and sediment combined shall not amount to more than 0.1 per cent.

Carbon residue: The carbon residue shall not exceed 0.5 per cent.

Precipitation test: When 5 cc. of the oil is mixed with 95 cc. of petroleum ether and allowed to stand 24 hr., it shall not show a precipitate or sediment of more than 0.25 cc. or 5 per cent by volume of the original oil.

Lubricating Oils

Oils for general lubrication purposes are divided into three classes by the Committee and a set of specifications has been drafted for each class. The service for which each oil is intended is as follows:

Class A: This specification covers the grades of petroleum oil used for the general lubrication of engines and machinery where a highly refined oil is not required. This oil is not to be used for steam cylinder lubrication.

Class B: This specification covers the grades of petroleum oil used for the lubrication of turbines, dynamos, high-speed engines and other classes of machinery where an oil better than Class A is required. The oil shall be satisfactory for use in circulating and forced feed systems.

Class C: This specification covers the grades of petroleum oil used by the United States Government and its agencies for lubrication of air compressors and internal-combustion engines, except aircraft, motorcycle and Diesel engines; also for the lubrication of turbines and other machinery where an oil better than Class B is required. This oil shall be satisfactory for use in circulating and forced feed systems.

Table 2 is arranged so that the points on which the specifications for the three oils differ can be readily compared. The paragraphs applying to all classes alike are listed under the table.

TABLE 2—COMPARATIVE CHART OF LUBRICATING OILS

	Class A	Class B	Class C
Acidity: The weight of potassium hydroxide required to neutralize 1 gram of oil shall not exceed	0.10 mg.	0.07 mg.	0.05 mg.
Emulsifying Properties: The oil shall separate[1] in 30 min. from an emulsion with			
1) Distilled water	Test not required	Test applies	Test applies
2) 1 per cent salt solution.			
3) Normal caustic soda solution.			
The demulsibility shall not be less than 300			
Carbon Residue: The carbon residue shall not exceed the following	Test not required	Test not required	per cent Extra Light 0.10 Light 0.20 Medium 0.30 Heavy 0.40 Extra Heavy 0.60

[1] This means that there shall be only a slight cuff between the water and the oil.

Only refined petroleum oils without the admixture of fatty oils, resins, soap, or other compounds not derived from crude petroleum, will be considered.

These oils shall be supplied in five grades, known as extra light, light, medium, heavy and extra heavy.

Flash and Fire Points: The flash and fire points of the five grades shall not be lower than the following:

Grade	Flash deg. fahr.	Fire deg. fahr.
Extra Light	315	355
Light	325	365
Medium	335	380
Heavy	345	390
Extra Heavy	355	400

Viscosity: The viscosity of the five grades of oil at 100 deg. fahr. shall be within the following limits:

Grade	Sec.
Extra Light	140-160
Light	175-210
Medium	275-310
Heavy	370-410
Extra Heavy	470-520

Color: The color of the extra heavy grade shall not be darker than No. 6 National Petroleum Association Standard, or its equivalent. The color of the other grades shall not be darker than No. 5 National Petroleum Association Standard, or its equivalent.

Pour Test: The pour test shall not be above the following temperatures:

Grade	Deg. fahr.
Extra Light	35
Light	35
Medium	40
Heavy	45
Extra Heavy	50

Corrosion: A clean copper plate shall not be discolored when submerged in the oil for 24 hr. at room temperature.

Further tests on oils of Class C may be required at the option of the Department of the Government using the oils.

Aviation Engine Lubricating Oil

Lubricating oils for use in aviation engines are covered by an individual specification separate from the group of oils for general lubrication purposes. A difference of opinion exists between the War and Navy Departments regarding the characteristics of a suitable oil for aviation engines and this has necessitated the inclusion of two distinct grades in the specification. They differ principally in viscosity, the Navy preferring the lighter oil, grade 1. Oil for lubricating motorcycle engines is purchased under this same specification which follows.

Liberty Aero and Motorcycle Oil

This specification covers the grades of oil used for the lubrication of stationary cylinder aircraft engines and motorcyles.

The oil shall be made from pure, highly refined petroleum products and must be suitable in every way for the entire lubrication of stationary cylinder aircraft engines and motorcycle engines operating under all conditions. The oil shall not contain moisture, sulphonates, soap, resin or tarry constituents which would indicate adulteration or lack of proper refining.

These oils shall be supplied in two grades, to be known as Grade 1 and Grade 2.

Flash Point: The flash point of the two grades shall not be lower than 400 deg. fahr. for Grade 1 and 500 deg. fahr. for Grade 2.

Viscosity: The viscosity of the two grades at 210 deg. fahr. shall be within the following limits:

Grade 1 (Summer)	90-100 sec.
Grade 1 (Winter)	75- 85 sec.
Grade 2	125-135 sec.

Pour Test: The pour test of Grade 1 shall not be above the following limits:

Summer 45 deg. fahr.
Winter 15 deg. fahr.

Cold Test: The cold test of Grade 2 shall not be above 35 deg. fahr.

Acidity: Not more than 0.10 mg. of potassium hydroxide shall be required to neutralize one gram of Grade 1 oil.

Emulsifying Properties: The oil shall separate completely in 1 hr. from an emulsion with distilled water at a temperature of 180 deg. fahr.

Carbon Residue: The carbon residue on Grade 1 shall not be over 1.5 per cent; on Grade 2, not over 2.0 per cent.

Precipitation Test: When 5 cc. of the oil is mixed with 95 cc. of petroleum ether, and allowed to stand 24 hr., it shall not show a precipitate or sediment of more than 0.25 cc. (5 per cent by volume of the original oil).

Transmission Lubricant and Cup Grease

The following specifications regulate the quality of oils purchased for use in transmissions and axles.

TRANSMISSION LUBRICANT

This specification covers the grade of petroleum oil used for the lubrication of transmission gears and bearings, differential gears, worm drives, winch drives, and roller and ball bearings used in connection with such parts of the equipment of motor vehicles.

The lubricant shall be a refined petroleum product, without the addition of any vegetable or animal oils or products derived from them, and be entirely free from fillers.

Flash Point: The flash point shall not be lower than 460 deg. fahr.

Viscosity: The viscosity at 210 deg. fahr. shall be within the following limits:

175 to 220 sec.

CUP GREASE

This specification covers the grades of cup grease used for the lubrication of such parts of motor equipment and other machinery as are lubricated by compression cups; Nos. ½ and 1 to be used in spindle cups or transmissions.

The grease shall be a well manufactured product, composed of a calcium soap made from high grade animal or vegetable oils or fatty acids, and a highly refined mineral oil.

The mineral oil used in reducing the soaps shall be a straight well refined mineral oil with a viscosity at 100 deg. fahr. of not less than 100 sec.

Soap Content: No. ½ cup grease shall contain approximately 13 per cent of calcium soap. No. 1 cup grease shall contain approximately 14 per cent of calcium soap. No. 3 cup grease shall contain approximately 18 per cent of calcium soap. No. 5 cup grease shall contain approximately 24 per cent of calcium soap.

Consistency: These greases shall be similar in consistency to the approved trade standards for Nos. ½, 1, 3 and 5 grease.

Moisture: The grease shall be a boiled grease, containing not less than 1 or more than 3 per cent of water when finished.

Corrosion: A clean copper plate shall not be discolored when submerged in the grease for 24 hr. at room temperature.

Ash: The ash shall not be greater than 1.7 per cent for No. ½ grease. The ash shall not be greater than 1.8 per cent for No. 1 grease. The ash shall not be greater than 2.3 per cent for No. 3 grease. The ash shall not be greater than 3.5 per cent for No. 5 grease.

Fillers: The grease shall contain no fillers such as resin, resinous oils, soapstone, wax, talc, powdered mica or graphite, sulphur, clay, asbestos, or any other filler.

Criticisms and Suggestions

The members of the Society are requested to study the specifications carefully in relation to their experience submitting their comments to the Chairman of the Committee on Standardization of Petroleum Specifications, M. L. Requa, Bureau of Mines, Washington. Copies of the specifications can be secured without charge upon application to the Director, Bureau of Mines, Washington, for Bulletin No. 5.

AMERICAN AERONAUTIC PILOTS

THE recent Pulitzer Trophy Race was further evidence that American pilots are as good as any in the world. Foreign authorities have laid great stress on the exploits of their pilots and some people in this country have received the impression that the United States is outclassed in that respect. It is an absolute fallacy. One of the principal reasons for the lack of mention of individual pilots has been the large number of first-class pilots at work in this country. The unfortunate dearth of aviation meets has allowed the daily papers to forget to some extent the existence of these men.

The aerial mail is an example of the public's forgetfulness of the excellence of the pilots employed. It is one thing to fly from one airport to another on a clear warm day, but it is a different proposition to take-off in a fog and fly through a snowstorm or two with the temperature below zero. That is what the mail pilots are required to do very frequently. Flying on schedule in storms requires a much higher order of piloting than incidental flying in the neighborhood of an airport. Many of the pilots in the mail service have had over 2000 hr. of flying. That figure may not seem much to the layman, but it requires steady flying for a few years to obtain it, or to put it another way, about 150,000 miles of travel.

The Army and the Navy have many pilots who can be classed among the best in the world. The race brought several of them into prominence and there are many more yet to be heard from. The Mineola-Alaska flight was as big a feat as the Cairo-to-the-Cape flight. It was much more of a success. There were no casualties and the same machines returned without major repairs. In the other famous flights that have been made since the war there is no instance of more than one machine completing its mission. Such public meets as the Pulitzer race allow the service pilots a chance for recognition. It is a maxim of military and naval affairs that good work is the duty of an officer and that publicity cannot be permitted. This is essential to discipline and coordination of effort. But in open competition with civilians in a sporting event or in performing some extremely hazardous enterprise such as crossing the Atlantic or flying to Alaska, it is due to the officer and his country that the facts be known. The public should not, because it does not know the names of the fine pilots we have, believe that they do not exist.—*Aviation.*

The Alaskan Flying Expedition

By First-Lieut. St. Clair Streett[1], U. S. A.

Washington Section Address *Illustrated with* Drawing and Photographs

DURING the latter part of December, 1919, the idea of an airplane flight to Alaska was conceived in the office of the Chief of Air Service. The advantages of such a flight were immediately evident, but it was not decided what type of equipment could be used; any plane decided upon would be called upon to exhibit a varied number of abilities. In February, 1920, instruction was given to prepare the proposal of this contemplated flight to Alaska for authorization by higher authority. Before this could be done, it was necessary to secure the consent and cooperation of the Canadian government to allow the flight over Canadian territory, and further to allow the shipment of the necessary supplies to points within the Canadian border.

In laying out the route, care was taken to have this along lines of communications, as well as by the shortest way possible. Every available source of information concerning British Columbia, Yukon Territory and Alaska was consulted; individuals who were conversant with the country were interviewed whenever possible to obtain a more human idea of the territory over which the flight was contemplated. When the route was finally decided upon, it was seen that more than half the distance to be covered lay over a most mountainous and sparsely settled country, all the maps of which we were able to obtain were incomplete and inaccurate.

On May 1, 1920, the final approval of the project was given by the War Department, and active plans for the flight were inaugurated. It was planned to have equipment and personnel ready to start by June 15, 1920. The undertaking of allocating in the short time available the material and supplies, as well as gasoline and oil, to such remote places as White Horse and Dawson in the Yukon, and Fairbanks and Ruby in Alaska, was indeed appalling. The approval of the flight contained authorization to send an officer ahead of the expedition to visit all the points at which planes were to stop, to arrange for proper landing fields, proper custody of supplies, and to obtain information for use on the flight. The start of the flight was postponed until July 15, due to the Reorganization Bill going into effect on July 1.

The DH4B air plane was finally chosen for the equipment, and the officers of the expedition designated as pilots proceeded with their mechanics to the factory where new planes of this type were being assembled after being converted from DH4's. These officers and men spent nearly two weeks going over the planes to make them comfortable and to remove all unnecessary weight and paraphernalia.

The Alaska flight, like every other cross-country flight attempted, depended greatly on communication facilities for its success. In this flight it was not possible to use any but the regular commercial means of communication. In flying over such an extended, unknown and in many places unchartered area, advance information on the weather was of especial importance. The Weather Bureau at Washington had agreed to furnish as much information on average conditions as was available, but after leaving the Eastern coast the weather prognostications from Washington were of little value. The local weather bureaus were to furnish forecasts for areas to be traversed. In Alaska itself the Signal Corps was to cooperate in furnishing data on the weather conditions.

[1]Air Service, Washington. Lieutenant Streett was in command of the Alaskan Flying Expedition which recently completed a successful airplane flight from New York City to Nome, Alaska, and return.

Start of the Flight

On July 15, 1920, at Mitchel Field, Long Island, the four planes were ready to leave the ground at 12.15 p. m. The pilots and mechanics of the expedition were given a final address, covering the instructions and policy governing the flight, by Brigadier-General William Mitchell. The flight took off at 12.33 p. m. in formation, circling the field, and took up its course, with compass bearing 298 deg., and all engines apparently running beautifully. Heavy weather was encountered 10 min. out of Mitchel Field in the form of fog and rain. The flight formation was broken up, it being almost impossible to see in the thick weather and possibility of collision being imminent. The cloud bank was approximately 2500 ft. thick. Planes Nos. 2, 3, and 4 went through clouds and flew at approximately 1000-ft. altitude through rain, while No. 1 climbed to an altitude of approximately 8000 ft., above the clouds, and held a compass course for Erie, Pa. At Wilkes-Barre, Pa., hail and rain were encountered in such volume as to force Plane No. 1 down through the clouds to seek a landing which was made in a wheat field about 8 miles east of Wilkes-Barre and an axle was broken in effecting it. Spare parts were sent immediately from Mitchel Field by rail, and the 16th was spent in making the necessary repairs on this plane before take-off could be made. The three other planes of the expedition had landed at Erie after a 5½-hr. flight, during which they encountered rain and fog almost the entire time.

On July 17, plane No. 1 left Elmhurst, Pa., at 8.35 a. m. and landed at Erie at 12.35 p. m., after an uneventful trip, with clear weather all the way, although against a considerable headwind. The country traversed between New York City and Erie has been considered rough by flyers, and is a territory on which natural landing fields are not frequent. The afternoon of the 17th was spent going over all four planes to make ready for the next day's hop to Grand Rapids.

It rained all day on both July 18 and 19. On July 20, after several attempts to take-off from a soft field, Lieutenant Crumrine finally succeeded and escaped serious accident by only a very narrow margin. The field was so soft that it was considered impracticable to tempt fate further by trying to get all four planes off before the field had been rolled. The afternoon of the 20th was spent in running a heavy truck up and down the field to pack the ground. We hired a team of horses to stand by to pull the truck out whenever it became stuck, which it did frequently. Word was received in the afternoon that Lieutenant Crumrine had safely landed at Grand Rapids.

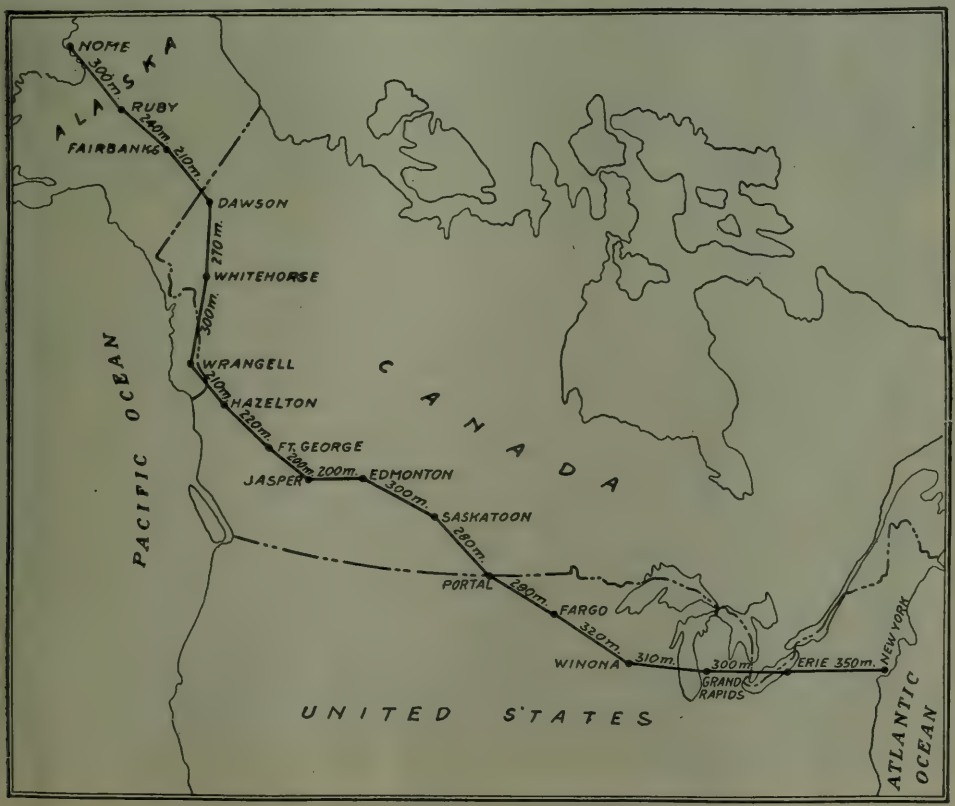
Everyone was on the field early on July 21 and the planes were ready. At 9.00 a. m. Lieutenant Kirkpatrick took-off and barely missed some trees, getting out of the

small field. Lieutenant Nutt and I followed him at about 1-min. intervals, and we both experienced sufficiently narrow escapes to thank the good Lord when we were finally in the air and circling over the field, preparing to strike out for Grand Rapids. After gaining sufficient altitude, we picked up the course and started across Lake Erie. After 10 min. the shore line dropped behind us, and at 7000 ft., due to the thick mists that prevailed, was soon entirely lost to sight. After flying for 70 min. entirely by compass without seeing more than one vessel on the lake, you can easily imagine our great joy when we finally descried the Canadian shore. The flight was over the upper end of Lake St. Clair, Selfridge Field and the lake region around Pontiac, Mich., finally ending at the flat region surrounding Grand Rapids. Landing was made at 12.20 p. m. Central Time, after 3 hr. and 20 min. in the air. The crews of the four planes remained on the field until 10.00 p. m., preparing for the next day's flight.

The planes took off at 11.30 a.m. on July 22, at about 30-sec. intervals. The flight formed at about 2000-ft. altitude over the field and we picked up our course 284 deg. to Winona, Minn., which took us directly across Lake Michigan at its widest point, from Grand Haven, Mich., to Port Washington, Wis. At 12.05 p. m. we were over Lake Michigan and had lost sight of the Michigan shore. The visibility was extremely poor. This entire section seemed to be covered by a smoke haze which attained a

THE COUNTRY NEAR WINONA, MINN.

height of 8000 ft., which was, incidentally, the altitude we maintained crossing the lake. It was again necessary to rely entirely upon the compasses for direction, and lonesomeness stimulated our imagination to the extent that the engines made various kinds of sounds, all of which seemed to prophesy engine failure, but when we sighted the Wisconsin shore at about 12.55 p. m., the engines appeared to be running beautifully. The country between Port Washington and Mauston was very marshy in



ROUTE OF THE ALASKAN FLYING EXPEDITION

NEARING THE LANDING FIELD AT SASKATOON, SASKATCHEWAN
There Are Miles and Miles of Uncultivated Land Similar to That Shown

places and would afford few good landing fields, but was indeed wonderful as compared with the monotonous waste of water of Lake Michigan.

The flight landed at Winona, Minn., at 2.45 p. m., after 3¼ hr. in the air. We had received an urgent invitation to stop at Minneapolis on our way to Fargo. This invitation we decided to accept, and preparations for take-off for Minneapolis from Winona were made the same afternoon. At 6.00 p. m. all the planes were again in the air circling over Winona and on the way to Minneapolis. It was one of the most beautiful flights we had experienced, flying up the valley of the Mississippi 100 miles just before sundown. When just east of St. Paul our flight was met by an airplane from the Curtiss Northwestern Aeroplane Co., Minneapolis, which escorted us to the landing field of the Twin City airdrome, where landing was made at 7.25 p. m. We were welcomed by a number of enthusiastic gentlemen, who were intensely interested in the future of aviation, and especially in its progress in the State of Minnesota.

July 23rd was spent in repairing and carefully looking over all machines prior to the flight to Fargo, which was proposed for the 24th. On July 24th our flight took off at 11.47 a. m., and after circling to an altitude of 5000 ft. we headed for Fargo. The atmosphere was so clear that one could see from 40 to 50 miles, and as this section in Minnesota is dotted with innumerable lakes surrounded by wonderful farms, our flight to the edge of the great prairie country was particularly beautiful. The flight to Fargo was made in 2 hr. and 24 min. Arriving at Fargo, we were given a welcome by a number of enthusiastic citizens, who were very much disappointed because we could not leave our planes to accept their kind invitation to lunch until after our engines had been carefully checked and the tanks refilled with gasoline and oil, which practice had been adopted and carefully carried out from the start.

A start was made for Portal, N. D., at 9.25 a. m. the next day. The engines were running beautifully. After take-off an altitude of approximately 4000 ft. was attained and maintained for the entire distance, 290 miles, to Portal, which was reached in 3 hr. and 10 min.

The territory flown over up to a point 200 miles north and west of Fargo was the flat wheat country for which this section of the United States is noted. Landing could be effected anywhere without danger of accident. From that point on, however, the bad lands of North Dakota were traversed. This country is interspersed with small saline lakes and is used mostly for cattle raising.

FLYING OVER CANADA

At Portal we crossed into Canadian territory for the first time. Our landing field was, in fact, on the Canadian side of the line. Landing was effected by all the planes without damage, and preparation was immediately made for the continued flight to Saskatoon on the 26th. We had begun to be very hopeful at this time with almost half our journey completed, and with weather that prom-

ised to remain favorable until we should reach the mountains of Alberta and British Columbia. Up to this time we had been using a type of oil furnished by the Air Service. Portal was the first stop at which we used Mobiloil B, which incidentally we continued to use from there on.

We left ground for Saskatoon at 10.05 a. m. July 26. The country from Portal to Regina was monotonously flat and almost treeless. North of Regina the terrain surrounding Last Mountain Lake was slightly hilly, and this beautiful body of water, which is not over three-quarters of a mile wide at its widest point, extends north and east from Regina for a distance of about 60 miles. It was while over this territory that we got our first idea of the wide expanse of the comparatively new country just over our border in Alberta and Saskatchewan. Thousands of acres of this land have never been tilled, and ranches and homes are thinly scattered over it.

The run of 290 miles from Portal to Saskatoon was negotiated in 4 hr. 15 min. We arrived at 12.07 p. m., having bucked a 20 m.p.h. wind all the way up.

On July 27 take-off was effected at 9.51 a. m., with the prospect of a beautiful flight with clear weather to Edmonton. The country due west of Saskatoon is spotted with innumerable small lakes and is very thinly settled. Most of the land is covered with a growth of swamp poplar, which is only from 15 to 20 ft. tall and very thick. There are several Indian reservations in this immediate section. Immediately west of this section, from the village of Rosehaven to the edge of Lake Manitou, cleared and tilled fields extend in every direction and landing would be possible at any place if proper care were exercised. We were bucking a headwind of about 20 m.p.h. A peculiar thing about it was that the wind was of apparently constant velocity anywhere from 100 ft. to 7000 ft. altitude.

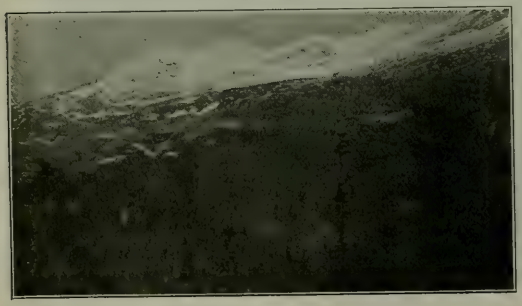
Edmonton was the last stop where supplies could be obtained and extensive work on airplanes could be done without the necessity of shipping supplies in; so we planned to give the planes a thorough overhaul to insure absolute fitness for the flight into the mountains. Two days were to be spent doing this work, but as two gas tanks had developed leaks, and it was necessary to disassemble almost entirely the planes to get the tanks out for repairs, we stayed at Edmonton a day longer than we had anticipated. On the 29th we left for Jasper, but were forced to return to airdrome at Edmonton after a flight of 1¾ hr., due to the fact that when almost at the mountains the visibility became so poor on account of storms coming down from the north that we were unable to proceed with any assurance of success.

On Aug. 1 at 9.37 a. m., a fresh start was made. We were forced to fly into a headwind of about 15 m.p.h., although the weather was beautifully clear and it was possible to see for many miles, after altitude was reached. Up to the Pembina River west of Edmonton and south of the Grand Trunk Railway, the country is tilled and rather thickly settled, but from that point on the country is

Bad Lands East of the Jasper National Park in Alberta
This Country Is Almost All Swamp and Looks Very Forbidding from an Airplane

VIEW TAKEN WHILE GOING THROUGH THE YELLOW HEAD PASS

wilder and rougher. Shortly after crossing the Pembina River we were able to discern at a great distance due west the white-capped peaks of the Rockies. About 15 min. later visibility became very poor, due presumably to smoke from forest fires in the vicinity of Jasper National Park and eastern British Columbia. This condition prevailed until we reached the eastern shore of the Athabasca River, at which point the atmosphere became clear again and we were able to proceed up the Athabasca to Jasper under a clear sky, which gave us a wonderful opportunity to admire the solemn grandeur of the Rocky Mountains which we were paralleling on our right. It seemed impossible that a place could be found large enough to land an airplane in all this great waste of rock and snow, but after flying up the Athabasca for about 15 min. we turned around the shoulder of a mountainous projection into the

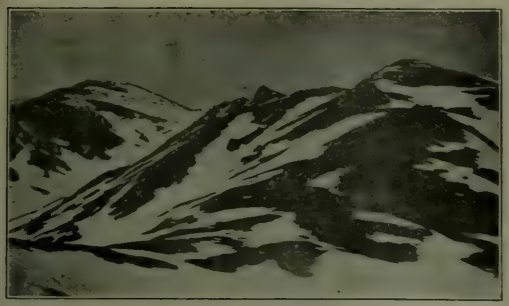


THE COUNTRY TO THE NORTH OF HAZELTON, B. C.

SUNSET ON THE ARCTIC OCEAN

valley, and a great level flat was exposed along the shore of the Athabasca, upon which we descried the signal smoke and landing cross which indicated our landing field. Landing was made at 11.15 a. m. Pacific Time, after a run of approximately 3 hr.

We landed on a natural flat that had been obstructed by occasional stumps and cleared by Col. Maynard Rogers and his park rangers. This was our first experience of landing in the wilds where airplanes had never been seen and natural obstacles seemed to forbid the use of air-



TYPICAL COUNTRY AROUND CAPE PRINCE OF WALES

craft. Our landing field was situated approximately 15 miles from the town of Jasper.

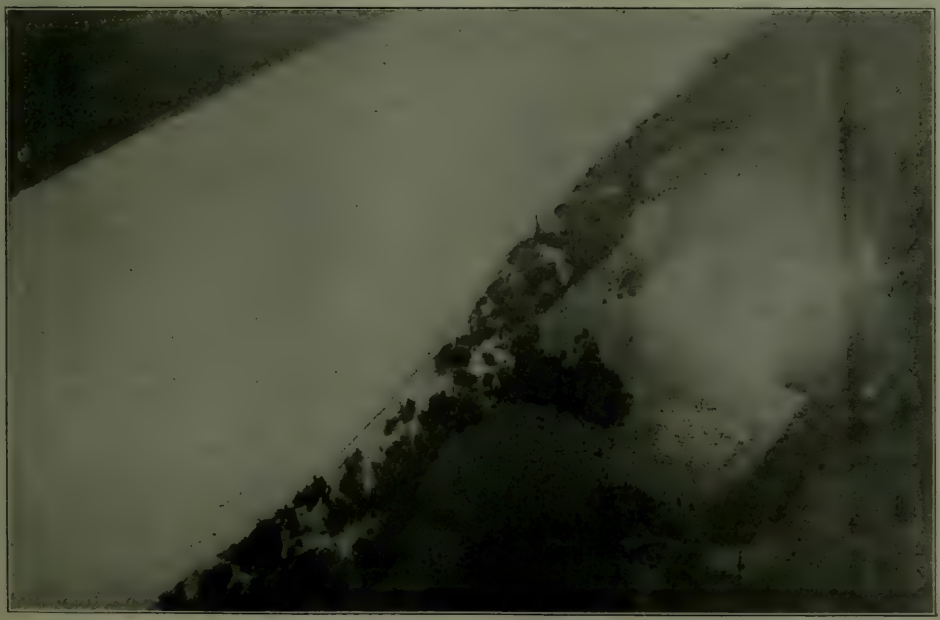
On the morning of Aug. 2 we prepared for an early departure. Leaving the ground at 8.30, we flew up the valley of the Athabasca River to the valley of the Miette, through which the railroad runs to Yellow Head Pass. In passing over the town of Jasper Plane No. 1 caught fire, due to the spraying of oil from reserve tanks over hot exhaust-pipes. This plane side-slipped to about 200 ft. over the Athabasca River and, accompanied by the three other planes, succeeded in getting back to landing field. After the safety of Plane No. 1 was assured, the remaining three planes of the flight, which were still in the air, resumed their journey to Fort George.

BAD WEATHER ENCOUNTERED

After removing obstructions in the oil-tanks, Plane No. 1 was again ready to fly. Take-off was made about 1.30 p. m., and after circling the field to be sure the engine was running properly, we headed over the slope of Pyramid Mountain for Yellow Head Pass. At the time of our take-off snowstorms were prevailing upon the highest peaks bordering the pass, while considerable rain could be seen at intervals in the pass itself. As we proceeded up Miette Valley we began to encounter thick smoke, caused by forest fires on both sides of Yellow Head Pass. Seven distinct fires were counted from about 3000 ft. over the town of Pocahontas, which is very near the summit. The smoke, in conjunction with occasional rain and hailstorms encountered, made the trip to the

THE TAKU GLACIER

pass an extremely uncomfortable one, and when once through we congratulated ourselves heartily. Before us in a straight line projected the valley of the Frazer River, which runs between the Rocky Mountains and the Caribou Range to the south. The slopes of the mountains in this area are completely covered with a heavy growth of fir, hemlock and spruce; the smell of evergreen was discernible even at an altitude of 8000 ft. The Grand Trunk



LOOKING DOWN ON THE YUKON RIVER AND THE SWAMPS WHICH EXTEND FOR MILES IN THE LOW COUNTRY ON BOTH SIDES OF THE RIVER

Pacific Railroad parallels the Frazer River nearly to Fort George, so that there was no difficulty in determining our exact location from time to time. After flying for ½ hr. down Frazer Valley, we began to encounter a strong headwind, which seemed of unvarying velocity between the altitudes of 1500 and 9000 ft. There was not much to choose in the matter of altitudes, it being impossible to land with safety within a radius of 50 miles.

At Hansard, we began to run into severe rainstorms from the southwest. The wind began to increase until a velocity of about 50 m.p.h. was reached. From Hansard to Fort George, a distance of approximately 35 miles, we were flying through continual storms and most of the time not over 200 ft. above the tree-tops. You can easily imagine our intense joy when Fort George was finally sighted through rain, which made it almost impossible to see even objects immediately below us. Landing was made at 5.30 p. m., after a 4-hr. run. In landing, due to poor visibility, we were unable to see objects directly ahead on the field, with the result that the left lower wing of one plane was damaged seriously by contact with stumps and trees. The other planes had landed without mishap earlier in the day.

Eleven days were spent at Fort George repairing the wing of the damaged plane and arranging for the cutting of grain on and leveling the field which was to be used for landing at Hazelton. On Friday, Aug. 13, all was made ready for the start to Hazelton. Superstition was thrown to the winds and, to prove that we were flying in the face of fate, we gave our mascot away. With all these odds against us we took-off at 8.55 a.m., and after a very beautiful trip unmarred by any unpleasant incident and over a very rough and rugged country, we arrived at Hazelton, the northernmost point touched by a railroad in North America. Landing was made at 12.20 p.m. At Hazelton the majority of the inhabitants had never before seen an airplane, and consequently we were a curiosity to them. Around Kispiox, which is just north of Hazelton on the Skeena River, are a number of Indian reservations, and naturally we were visited by a great number of natives from this place, whose curiosity was boundless. The airplane was dubbed by them as the 'steamboat of the air." The people of Hazelton were extremely cordial, and we were banqueted by the veterans of the Great War. On Aug. 14 we spent the entire forenoon rolling the field and preparing our planes for what we considered our hardest jump, that from Hazelton to Wrangell over the Coast Range. This territory over which we were to fly was a stretch about which very little was known, and upon which very little data had been obtained. It was known that a great many glaciers existed immediately between Hazelton and Wrangell, over which we would have to cross.

Flying Over Mountains and Glaciers

At 1.30 p.m. all the planes were in the air and the start for Wrangell was made. The country crossed up to the River Nass was much the same as that which had been traversed between Fort George and Hazelton, but after leaving the valley of the Nass we were obliged to climb to an altitude of about 10,000 ft. to enable us to cross the mountains. On the very crests of the wide ridges were glaciers of immense area, and valleys so shallow that even as late as the time when we crossed they were filled with snow. This area offered absolutely no possibility of landing, and we were distinctly glad when we reached Steward Arm, which indicated that we were nearing the coast. From this point we began to encounter high clouds of increasing thickness, which became greater in number and size as we neared the coast. We were unable for long periods of time to see anything below us at all. In the immediate neighborhood of Wrangell the weather was temporarily clear, and landing was made on Sergief Island at the mouth of the Stikine River at 4.30 p.m. The field was a marsh which was dry at low tide, but unfortunately when we arrived there was about 6 in. of water on it. The surface under the water was firm, and no damage other than a thorough wetting was experienced by us.

We were back in American territory at last and really felt quite at home. The people of Wrangell had come to Sergief Island en masse and welcomed us most heartily. By 7.30 p.m. our planes had been gassed and oiled and all preparations made for the flight to White Horse on the 15th.

The 15th proved cloudy and an impossible day for a flight to White Horse. On the 16th all were ready to go at seven o'clock in the morning, but we were unable on account of local weather conditions to leave the field before noon, and then it was possible only to take-off one at a time from a narrow strip of ground around the center of the field that had not been reached by the tide which was gradually covering the field. Three planes were barely able to get into the air on account of the rapidly rising water. In fact, the water rose so rapidly that Plane No. 1, which was taking-off last, was unable to get off that day.

Plane No. 1 took-off Aug. 17 at 8.50 a.m. The run as far as Juneau was with a favorable wind and under clear skies, but after passing Juneau clouds began to blow in from the Pacific rapidly, and within ½ hr. after leaving Juneau we were flying not over 500 ft. above the water of the Lynn Canal. After passing Fort Haynes, the fog began to lift somewhat, and when Skagway was reached it was seen that the clouds were high enough to permit crossing Chilkoot Pass at an altitude not much exceeding 100 ft. After crossing the summit, the bad weather was left behind, and the flight from the summit of Chilkoot Pass to White Horse was ideal. Landing was made at White Horse, Yukon Territory, at 1.05 p.m., after a very beautiful and interesting trip.

Planes Nos. 2 and 4 took off at 3.00 p.m. the same day for Dawson, to be there in time to participate in the celebration of the Discovery Anniversary, which is held on Aug. 17 every year in commemoration of the Klondyke strike. It was contemplated that Lieutenant Crumrine and I should go along, but unfortunately on the take-off he blew a tire, and by the time it could be mended it was too late to permit our arrival at Dawson before sundown that day. Take-off was effected for Dawson at 6.14 a.m. on the morning of the 18th. Our flight took us over the historic Lake Le Barge and the Yukon trail, which the gold seekers followed in the Klondyke rush. We passed directly over the towns of Carmacks, Yukon Crossing and Selkirk on the Yukon River. From that point we followed the Wounded Moose trail from Pelly over the mountains away from the Yukon River to the valley of the Stewart River, over Stewart Crossing, striking the Klondyke River just south of Dawson by way of Bonanza Creek. At Dawson we were given a most remarkable reception. Everyone who was physically able was out at Faulkner's Ranch to greet us.

Our engines were all running beautifully up to this point, and as no work was necessary on our planes, they were made ready for an immediate departure for Fair-

banks on the 19th. At 10.52 a.m. of that day, all the planes had left the ground, and struck for the headwaters of the Forty Mile River on our way to Fairbanks. To fly from the valley of the Yukon to the valley of the Tannana, in which Fairbanks is situated, it is necessary to cross the Alaskan Range, whose lowest point was fortunately at the very point where our route crossed it in a direct line from Dawson to Fairbanks. It was over this country that we had expected to see the immense caribou herds, of which we had heard so much talk at Dawson, but unfortunately during our entire trip we saw nothing living from the time we left Dawson until we reached Chena Slough. The intervening country was as barren as any we had crossed, there being very little verdure except stunted poplar which clustered on the slopes and in the valleys of the then dried-up waterways.

The valley of the Tannana offered a striking contrast to the country over which we had flown, with its green fresh look and its abundant verdure. Landing was effected at Fairbanks at two o'clock, 3 hr. and 8 min. after our departure from Dawson. Our reception was most enthusiastic. Mines and projects for miles around were deserted; everybody had made it his business to be present when the airplanes landed. The landing of the first airplane in Alaska impressed the people of this country as being a great event, and they were prone to give as much credit for it personally, without taking into consideration the wonderful attributes of the modern airplane.

Excellent Condition of the Planes

Fairbanks was the point we had picked at which to outfit and repair planes in case of necessity, and consequently most of our supplies were allocated there; but due to the splendid condition of the planes and the engines, and to the increasing lateness of the season, it was considered advisable to push on the next day to Ruby, our last stop before reaching Nome, our destination. The weather on the 20th, however, prevented our taking-off that day, and on the 21st it seemed that unfavorable weather would bar our further progress. But the weather cleared sufficiently by noon to permit our take-off, which was made at 12.20 p.m. When 15 min. west of Fairbanks we began to encounter rain. We continued to fly through rain for almost ¾ hr.; in fact until Harper's Bend on the Tannana was reached. At this point the weather began to clear and the remaining 100 miles to Ruby was made through a clear beautiful sky.

We had been flying down the valleys of the Tannana and the Yukon Rivers during the entire trip. The borders of these rivers for miles, both north and south, constitute the most impenetrable swamps imaginable. Lieutenants Nutt and Crumrine, who were prominent in the search for Lieutenant Niergarth in the Florida Everglades, made the statement that the swamps of Alaska are by far the most formidable they had encountered. After 2¾ hr. in the air a landing was made at 3.05 p.m. near Ruby on a sandbar left dry shortly before by the recession of the river.

The Indians on the Yukon had forsaken their season's fishing, waiting for the airplanes to arrive from the east, and were present in great numbers when landing was made at Ruby. We have since been told by persons who were present that the Indians were frightfully perturbed when the planes were swooping about, preparing to land, but after the landing was made and they saw that the airplane is operated by man and not a monster of mythology, they were completely reassured and their curiosity got the better of their fears.

At Fairbanks on the Return Trip from Nome

Our engines had been performing splendidly throughout the entire trip. A landing was made without any mishap and our flight to Nome was planned for the 21st. Unfortunately, the weather on that and the following days was so poor as to prohibit the trip, but at 3 o'clock on the 23rd preparations were made for an immediate take-off with weather showing signs of clearing. At 3.15 p.m. the flight started the last leg of its journey to the northernmost city of the American continent.

From Ruby to Nulatto on the Yukon River the terrain traversed was much the same as that from Fairbanks to Ruby; the same dreary expanse of impenetrable marsh. The flight from Ruby to Nome was hindered considerably by the necessity of flying around small rainstorms. At Nulatto we left the Yukon and started to cross the mountains to Norton Sound. We ran into most disagreeable weather which made it impossible to maintain an altitude greater than that necessary to just clear the tops of the highest peaks, and during the intervening time we were passing through almost continual rain. At last Norton Sound was sighted, and after passing through a short snow flurry, we finally burst again into sunshine, which prevailed for the rest of the trip as we proceeded up the coast from Bald Head to Nome. Landing was made at 5.50 p.m., after about 3½ hr. in the air.

The entire flight from New York City to Nome, a distance of 4502 miles, had been accomplished in approximately 59¼ flying hr., at an average of 77.51 m.p.h. After the landing was made, each pilot reported his engine in condition warranting our attempt to return to the United States with our original powerplants.

The people of Nome were as pleased with the fact that we had successfully made the trip as we were, and considered our advent as an exemplification of a means of transportation which can in the near future be turned into channels by which they will be able to surmount a great many of the difficulties that arise with their present poor means of communication.

WORLD DEBT AND PAPER CURRENCY

THE growth in world debts and paper currency has not been checked by the return to peace. The additions to world national debts, which averaged $40,000,000,000 per annum during the war, were $44,000,000,000 in first year following the armistice and $42,000,000,000 in the year just ended, the second peace year. The additions to the world paper currency, which averaged $9,000,000,000 per annum during the war, were $12,000,000,000 in the first peace year and $25,000,000,000 in year just ended.—National City Bank.

ACTIVITIES OF THE SECTIONS

Sections Calendar

BOSTON
March 18

BUFFALO
April 19—Carbureter Performance. F. C. Mock

DAYTON
May 3

DETROIT
March 25—Relation between the Industry and the Department of Engineering Research at the University of Michigan. Prof. E. A. White

April 22

METROPOLITAN
March 10—Brakes. H. G. Farwell
April 14—Low-Grade Fuel Carburetion. R. H. Beach

MID-WEST
March 11—Storage Batteries

MINNEAPOLIS
March 2—Good Roads and Equipment
April 6—Repair Equipment

WASHINGTON
March 18—Highway and Highway Transport Meeting
April 1—Aeronautical Meeting
May 6

PROF. C. A. NORMAN of the Ohio State University gave some interesting facts before the Minneapolis Section on Feb. 7 on the subject of Fuel and Fuel Substitutes. He quoted the United States Geological Survey as predicting the exhaustion of petroleum supply with the present rate of use in a very few years, but suggested that the adaptation of the solid-injection engine to automotive use would double the time through which the present supply of petroleum would last. The speaker discussed various fuel mixtures including benzol and alcohol, pointing out not only their chemical and physical properties from the standpoint of desirability as engine fuel, but also their economic feasibility. While it is possible to produce sufficient alcohol from certain crops as far as available land in this country is concerned, the alcohol could not be produced by this method at a cost sufficiently low to warrant the development of an industry for the purpose.

Professor Norman advocates the immediate development of the shale-oil industry believing that it is important that a beginning be made in order that proper processes can be worked out for lowering the cost of production in this field.

At the conclusion of the paper, the Story of Petroleum film, produced by the Bureau of Mines, was shown.

The Metropolitan Section held a meeting on Feb. 17 at Cooper Union, New York City, at which Ethelbert Favary presented a two-part paper on The Calculation of Motor Vehicle Frame Stresses, in connection with which materials were tested in the laboratory on a machine having an automatic recording attachment showing elastic limit, yield-point, elongation and ultimate strength, and on the testing of engines by dynamometers, manographs and O'Kill pressure indicators. In the laboratory tests were made disclosing the ratios of maximum pressures to compression pressures at various throttle openings, as well as the maximum pressure with cylinders thoroughly scavenged. At the dinner preceding the technical session, Magistrate House of the Traffic Court of New York City gave a talk on matters of importance to the automotive engineer.

R. E. Lippert told the members of the Cleveland Section something of the various systems of drying used in painting processes at the meeting of that Section held on Feb. 18.

The Fuel Problem in Terms of Miles per Gallon was the subject presented by O. C. Berry at the Detroit Section meeting of Feb. 25. On the same evening the Boston Section held a session at Springfield, following out the program of this Section to hold meetings at various automotive centers in New England.

On Feb. 25 the Pennsylvania Section held a session at which the general subject was automotive vehicle equipment. The Buffalo Section discussed Temperatures in Internal-Combustion Engines at its meeting of Feb. 23.

Members of the Society resident on the Pacific coast, in response to the invitation issued by the local committee at San Francisco, attended the first of a series of luncheons at the Palace Hotel in that city, 56 being present. Lawrence P. Wagner of the Standard Oil Co. addressed the group on the subject of lubrication. The formation of a Section of the Society in San Francisco or the holding of a series of technical meetings there under the auspices of members of the Society was discussed. Another luncheon for further discussion of this matter is scheduled for this month.

FITS FOR CYLINDRICAL PARTS

THE classes of fits which apply to cylindrical parts may be approximately summarized as follows: (*a*) running fits, where one part must revolve freely; (*b*) sliding fits, where one part must slide freely; (*c*) push or dowel fits, where neither part is required to revolve but where both parts must assemble readily and be held in alignment; and (*d*) force, driving or shrinkage fits, which are made with pressure or by shrinkage and used in assembling parts which must be held in fixed positions.

The amount of the minimum clearance for a running fit is dependent, to some degree, on the length of the bearing; a long bearing may have a somewhat greater clearance than a short one. The proper length of the bearing depends on the load and the material used in the bearing. The load controls to a large extent the diameter of the bearing. The first step toward standardizing the minimum clearances is to determine the most common material employed in making the bearings, and to establish standard lengths of bearing for the various diameters of shaft. The exceptions which will inevitably develop must, of course, be treated on their own merits. Take, for example, a long feed-screw or a long bending roll which is supported at the ends. Regardless of the diameter or the length of the bearing, greater minimum clearances than the established standard would be required. If the number of similar exceptions is appreciable, supplementary standards can be developed to meet them.

Another factor which must be considered before the standards can be safely established, relates to the conditions under which the parts must operate. Thus, if the parts must operate when subjected to higher or lower temperature than normal shop temperatures, due allowance must be made. On the other hand, if such temperatures are the exceptions, the corresponding clearances must be exceptions.—Earle Buckingham in *Machinery*.

Dilution of Crankcase Oil[1]

By William F. Parish[2]

Illustrated with Charts

During the past few years the petroleum industry has been able to meet the tremendous demands for internal-combustion engine fuels only by turning out products that have been becoming gradually heavier and less volatile. The use of these heavy fuels in engines designed for the use of the lighter and more volatile fuels has brought about an unbalanced condition of the fuel, the engine and the lubricating oil. This condition has developed the dilution problem. Dilution, as a problem, has been brought forcefully to the attention of engineers during the last 2 years. The condition existed before but, due to the fact that the fuels in use were more volatile, the thinning of the lubricating oil did not bring it to a point where it would not support lubrication. In the four-cycle engine leakages always occur, irrespective of the nature of the fuel used. The effects of these leakages on the lubricating oil differ. With casinghead gasoline, natural or artificial gas, the leakages do not combine permanently with the lubricating oil and there is no dilution.

Dilution of the lubricating oil in an engine operating on the heavier of the liquid fuels is due to three causes: (*a*) the gas mixture escaping past the piston-rings during the compression stroke, (*b*) the lubricating oil on the cylinder walls, which has become diluted with fuel during the admission and compression strokes, leaking back into the crankcase, and (*c*) decomposition or "cracking" of the lubricating oil that has been thrown against the underside of the pistons or other heated surfaces.

The piston travels through two revolutions to allow the completion of the four cycles necessary to produce the power. A short discussion of what takes place in the cylinder and crankcase will set forth clearly the various stages leading up to dilution. For example, consider a clean engine and new, clean oil. The piston is on its upward or exhaust stroke. It is during this stroke that the cylinder wall receives its best film of lubricant, the oil being carried up by the rings and piston. The return or admission stroke creates a partial vacuum in the cylinder. This brings in the fuel mixture, which comes in contact with the film of lubricating oil on the cylinder wall. Some of the fuel in the mixture combines with the lubricating oil, reducing the body of the film as it becomes diluted. The diluted oil has more of a tendency to drain back into the crankcase than undiluted oil. During the return stroke the fuel mixture is compressed to as high as 35 lb. per sq. in. The greatest dilution of the film on the cylinder walls occurs during this stroke. Also, during this stroke the film of oil should be the strongest, to seal the space between the rings and cylinders properly. With all four-cycle engines some leakage of the fuel mixture takes place during the compression stroke. The amount of leakage depends upon the mechanical fit of the rings and the perfection of the seal formed by the lubricating oil. The mixture that escapes has all of the component parts of the fuel mixture in the cylinder at the time of the leakage and the fuel content is absorbed by the lubricating oil.

During the first part of the power stroke the film of oil on the upper part of the cylinder walls is largely destroyed, the volatile products combining with the fuel. The lower part of the film resists the reduced heat of the gases to an increasing extent as the gases expand. Carbon is formed as part of the decomposition of the lubricating oil during this stroke. Carbon deposits are heaviest where destruction of the film is greatest. There is practically no leakage of unconsumed fuel except as it has combined with the lower oil film. There is less possibility of leakage of fuel or of the unconsumed heavy ends during the power stroke than during the admission and compression strokes. At the completion of the power stroke, the oil film on the cylinder walls is in the poorest condition. This is remedied by the return or exhaust stroke when a new supply of oil is put on the walls.

Crankcase Conditions

During every throw of the cranks, oil is splashed up inside of the pistons. The heat cracks the oil, liberating a volatile portion which flows into the crankcase and aids dilution in exactly the same way as the leakages of the same boiling-point fractions from the fuel. The amount of diluent in the oil after a period of operation depends upon the nature of the fuel, the kind of lubricant and the general heat of the engine and the surrounding atmosphere.

There is no dilution when the engine is operated with natural or artificial gas. In this case the lubricating oil gets heavier. If the heaviest of the fuel distillates is used in the same engine and under the same conditions, the leakages combining with the oil make a mixture of various proportions of lubricant and fuel, the exact amount of each entering into the mixture depending upon the nature of the fuel being used, the original body of the lubricating oil and the temperature at which the oil and the engine operate. This mixture will remain constant with the same fuel, oil and engine temperature. As the engine operates at higher temperature, more of the fuel distills off and the proportions of lubricant in the mixture in the crankcase are consequently greater and it is thicker. Conversely, when the engine operates at lower temperature, more of the fuel is retained and dilution is, in consequence, greater and the mixture is thinner. Dilution difficulties are, therefore, more pronounced in winter than in summer. The amount of lubricant that works into the upper parts of the cylinder and is consumed depends upon the body of the lubricant. Thick oil works up very slowly and is, consequently, consumed less rapidly than thin oil.

The lubricating oil is an important factor in the dilution problem. Thick oil resists the dilution of the film and therefore drains less. Thick oil presents a more perfect seal and checks the escape of the gas during the compression stroke. Thick oil, as a rule, will decompose at a higher temperature than thin oil; therefore it will resist destruction better. In the same engine, with the same fuel and temperatures, for the same period of time, dilution will be greater with the thinner oil.

The fit of the piston-rings in their grooves and their free action against the cylinder walls control to a great

[1] Paper read at the annual meeting of the American Petroleum Institute, Washington, Nov. 18, 1920.

[2] M.S.A.E.—Consulting engineer, Chicago.

extent the amount of leakage of the diluted film and the gas. A more perfect lubricating seal can be produced by applying new oil directly to the rings, as in the practice of lubricating the larger gas engines. The new lubricating oil should be selected on the basis of its condition in the engine, so that it can work properly with any increased clearances that are due to operation and wear. By carefully controlling the mechanical and lubricating conditions, dilution in the same length of time will be less but will not be prevented.

Over-lubrication results if too much lubricating oil works up to the top of the cylinders. This keeps the tops of the pistons, the valves and spark-plugs "wet." Wet spark-plugs are insulated and their effectiveness is reduced. If the spark-plug ceases to function, due to this condition and to the after-effect of fouling, where there is an excess of wet carbon, all the fuel entering that cylinder is wasted. The cylinder becomes cooler and the fuel condenses more readily. Leakage and draining will increase and dilution become more rapid from this cause.

Friction and Power

The changes that take place in the fuel consumption of an engine operating under test conditions are partially due to temperature and its effect upon the body of the lubricating oil and to dilution of the lubricant. The method of determining the amount of dilution in oil drained from the engine at various periods varies with different laboratories. All of the methods proposed do not allow the removal of the exact amount of diluent carried by the lubricant. This is due to the diverse nature of the different lubricating oils and to the manner in which they act under the methods of treatment to remove the diluent.

In the experiments described each lubricating oil tested was treated individually. Samples of the oil were made with different fixed amounts of kerosene, the specific gravity of each sample being determined. This permitted a chart to be made showing the relation of specific gravity to percentage of dilution. By securing the specific gravity of the same oil taken from the crankcase, it was possible to determine the dilution. These samples were tested for viscosity on the Saybolt universal viscosimeter at 100 and at 120 deg. fahr., the average temperature of the oil going on to the bearings having been determined as being 120 deg. fahr. These data allowed the making of a chart of viscosity as related to percentage of dilution. When a sample of diluted oil was removed from the engine, it was immediately tested for viscosity at 120 deg. fahr. and then for check at 100 deg. fahr. From these findings the dilution could be readily secured. Finally, as a check, a mixture of the fresh oil and kerosene was made and a complete distillation secured so that the usual chart could be made of percentages against temperatures. The figures secured by distillation of a sample of the oil removed from the crankcase were plotted over this chart. The distillation charts show that the used oil from the engine contains more volatile products for the first half of the curve, but apparently more heavy products for the last of the distillation range.

Fig. 1 shows the curves already described. The data given on Fig. 2 are most interesting and have been made from a great many tests. This is a standard chart to show the influences of the various factors. The engine is required to develop a steady and fixed brake-horsepower at 1500 r.p.m. The engine is perfectly clean for the test and has been filled with new oil. This oil has been tested as described and shown in Fig. 1, so tables are ready to check the dilution. An excess of 4 oz. more than the regular filling is put into the engine. At the end of 1 hr. oil to the amount of 4 oz. is removed from the circulating system supplying the bearings. This sample is immediately tested for viscosity at 120 deg. and 100 deg. fahr. on the Saybolt universal viscosimeter. The specific gravity is then taken at 60 deg. fahr. At the end of the second hour a second sample of oil is removed and the first sample is poured back. For the remainder of the tests there is always 4 oz. of oil out of the engine being tested for viscosity and specific gravity, so the percentage of dilution can be determined.

The two viscosity curves near the bottom of Fig. 2 represent the actual viscosity of the samples removed hourly. The amount of dilution shown on the lower curve is taken after comparing the viscosity to the percentage of dilution on Fig. 1. Specific gravity is used as a check. It transpired that more accurate results were secured by operating on the basis of the viscosity determinations, as the viscosity could apparently be determined much more accurately than the specific gravity.

The temperatures in one series of tests were very accurately taken by thermocouples attached to the bearings and in the oil lines. The line on Fig. 2, showing bearing temperature rise above the temperature of the incoming oil, indicates clearly the changes that take place in the engine because of the changed condition of the lubricating oil due to temperature and to dilution. The line of bearing temperature must be compared to that of friction-horsepower, which starts off high when the oil is cold and drops as the oil becomes thinner due to heating and dilution. The changed friction-horsepower shows the proper influence on the fuel consumption after the first hour.

There are two remarkable features about all the charts that have been made on this work. First is the low fuel consumption during the first portion of the run, with its rapid rise during the first hour. Second is the gradual upward trend of all lines toward the end of the tests. The obvious explanation of the comparatively low consumption of fuel during the first part of the first hour's run is that when the oil is cold and undiluted it acts as an almost perfect seal, preventing leakage of the fuel mixture and allowing the engine to develop its full power and speed with a minimum consumption of fuel. Tests have been made in developing a method of applying new oil directly to the piston in an attempt to overcome dilution difficulties. It has been found that application of new cold oil will reduce the fuel consumption as much as 10 per cent, compared to ordinary lubrication with diluted oil. This seems to check the peculiar hump on the fuel-consumption chart.

The high fuel consumption at the end of the first-hour period is due undoubtedly to the fuel leakage caused by the breaking down of the seal as a result of dilution and by the high internal friction of the new oil. The gradual drop in the line to the sixth-hour period is caused by the more free operation of the lubricant, as indicated by the reduction in temperature of the bearings and the reduced friction of the engine. The rise in fuel consumption after the sixth-hour period is clearly caused by a gradual thickening of the oil due to the carbon and metal deposits it is carrying with it. The viscosity and gravity readings have been taken on the oil as it was taken from the engine. During the last period it was determined that by filtering the foreign matter out of the samples the viscosity was somewhat

more constant, but as the oil in the engine operated with this deposit, it was put through the viscosimeter in this condition. As the bearing temperature rose, after the tenth-hour period, this affected the amount of dilution in the oil as shown by the increase in viscosity with less dilution.

It is well known that in the Air Service oils must be removed from engines after periods of about 5 hr. operation. The reason for this is that the oil becomes so thick that it will not operate properly in the lubricating system. This thickness is caused by carbon that forms through the decomposition of the oil and then gets into the circulating oil. It is perfectly reasonable to expect the friction of the engine to increase as the oil gets thick

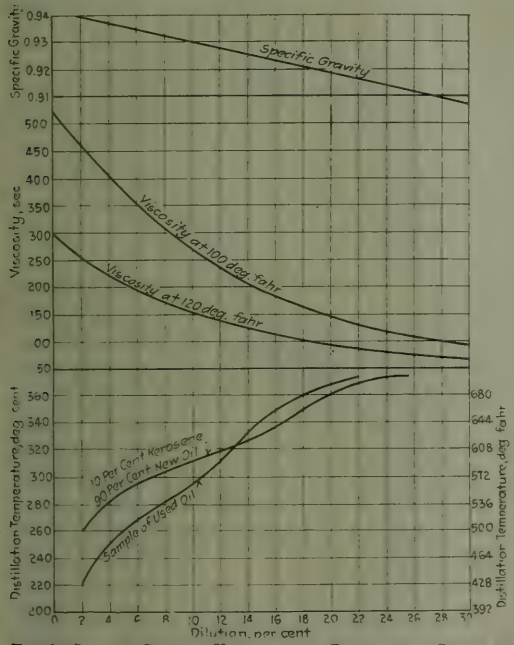


FIG. 1—SPECIFIC GRAVITY, VISCOSITY AND DISTILLATION CURVES OF A MIXTURE COMPOSED OF 10 PER CENT OF KEROSENE AND 90 PER CENT OF LUBRICATING OIL

from any cause. In the tests represented by Fig. 2 such increased friction is indicated.

RECLAMATION OF USED ENGINE OIL

Processes developed for the reclamation of used oil from internal-combustion engines utilize the heat from

TABLE 1.—USED AND RECLAIMED OIL

	Dirty Oil	Reclaimed Oil
Specific Gravity, deg. Baumé	28.4	26.2
Flash Point, deg. fahr.	140	320
Fire Point, deg. fahr.	180	385
Pouring Point, deg. fahr.	Zero	25
Viscosity, Saybolt sec.		
At 100 deg. fahr.	99	228
At 130 deg. fahr.	68	117
At 210 deg. fahr.	42	49
Carbon (Conradson), per cent	0.56	0.34
Dilution at 600 deg. fahr., per cent	16	4
Water, per cent	1	...
Ash, per cent	0.170	0.003
Sediment, by weight, per cent	0.44	None

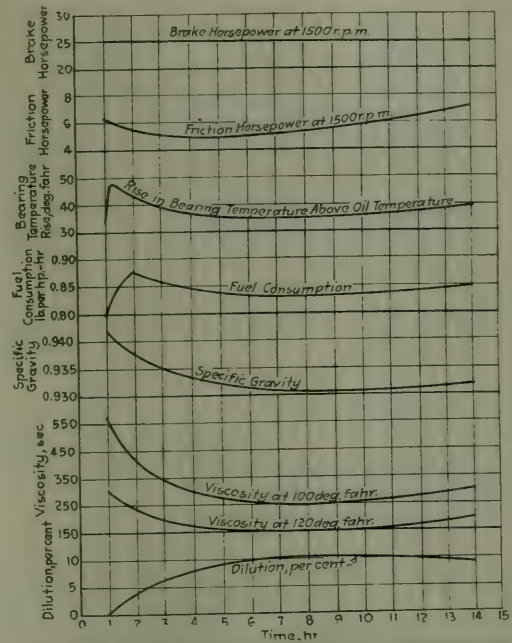


FIG. 2—RESULTS OF TESTS MADE ON AN ENGINE TO DETERMINE THE EFFECT OF DILUTION OF CRANKCASE OIL

steam. The results that can be obtained by treating diluted and carbon-contaminated oil in one of these systems will help to promote a general understanding of the subject. Oil collected from a number of motor trucks was placed in a reclaimer similar to those used by the Air Service during the war. Samples of the dirty oil put into the reclaimer and of the oil removed every hour during the reclamation process were carefully examined. Table 1 gives the details of the dirty oil and the reclaimed oil.

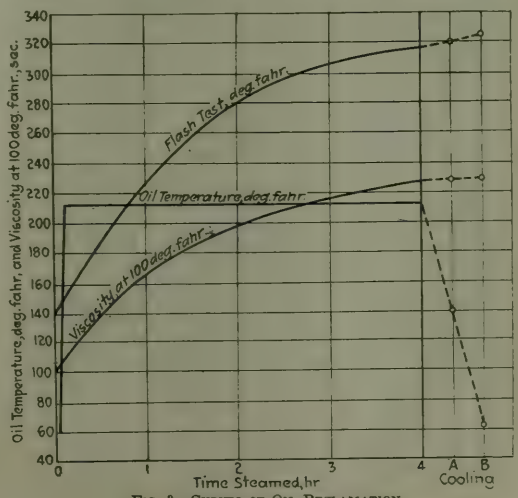


FIG. 3—CURVES OF OIL RECLAMATION

Fig. 3 shows the flash point and the viscosity of the oil in a reclaimer as it was undergoing the process of steaming to remove the diluent. The temperature of the oil was 60 deg. fahr. before the steam was turned on. The temperature rose to 212 deg. fahr. in the first 7 min. and remained at that point until the steam was shut off. During the next 30 min. the temperature fell to normal. The total dilution of the dirty oil was 16 per cent as determined by distillation up to 600 deg. fahr. The total amount of sediment by weight was 0.44 per cent. The process removed all but 4 per cent of the diluent and all of the sediment. The outstanding feature shown by Fig. 3 is the constant increase in flash point above the temperature of the oil, the diluent being carried off by the steam. There is an increase in the flash point after the steam has been turned off and the oil has cooled down. After steaming, the oil had a flash point of 305 deg. fahr. Two days later, three samples taken directly after the steaming process each showed a flash point of 325 deg. fahr.

The process as developed to date is not perfect, but indicates what can be accomplished in the way of reclamation. It has been developed sufficiently to show that reclaimed oil is a satisfactory lubricant for use in internal-combustion engines.

THE DISCUSSION

W. F. PARISH:—With reference to Fig. 2, if this were any kind of machine other than a gasoline engine, as the cold oil got into action the consumption of fuel would be at its highest instead of at its lowest point. The power curve should start in high and fall off gradually as the temperature of the oil increased, in tests on these gasoline engines. It does not do so. The only reason for the fact that the consumption of fuel per brake-horsepower-hour is 10 per cent lower on these curves at a time when it ought to be the highest, if we take the rules of lubrication and of mechanics into consideration, is that a better piston seal is produced in that engine at a time when the oil is cold and undiluted. No other conclusion is possible. If there were fuel leakage, if the rings were continuously tight and we could get a perfect mechanical seal, the fuel curves would start high with the cold oil, dropping as the oil temperature increased, but the fuel consumption would be 10 per cent below the entire present curve. Conversely, if the rings were very much out, there being no mechanical or lubricating seal, the curve would show a very high fuel consumption per horsepower-hour, representing the greater amount of fuel required to operate the engine plus the large loss of fuel during the compression stroke.

In the discussion of my paper on Castor Oil Versus Mineral Oil for the Lubrication of Airplane Engines, presented before the Mid-West Section of the Society of Automotive Engineers recently, a speaker stated that his company had a system of chassis lubrication by which oil was forced in under pressure to every point, including the engine. His company had been experimenting for many months. They had determined that by feeding as little as 22 drops per min. per cylinder to the piston-rings they could not only support lubrication perfectly but that this actually allowed the engine to operate with 10 per cent less fuel per brake-horsepower than when the same engine was lubricated with diluted oil splashed up from the crankcase.

We are building an engine that during the most important cycle, the compression stroke, has a basic defect that allows actual leakages of fuel past a supposititiously light seal. We are operating almost 10,000,000 four-cycle automobile, tractor and stationary gas engines that have this wrong basic principle, where worse results are produced as the engine wears. From a lubricating standpoint, we cannot improve the situation very well in these engines as they exist, because the heavy ends of the present fuel get into the crankcase and still further lower the seal effectiveness of the lubricant.

My men examined all the motor vehicles they could handle during last winter and continued the work well into the summer. They requested drivers to continue the use of the same gasoline from the same filling station for the period during which we wished to observe dilution conditions in their cars and trucks. Samples of oil were taken from time to time, reports were secured from the Weather Bureau of the average temperature and humidity of the day, and the oil analysis work was done in the same laboratory. In investigating in this manner the condition of everybody's oil and of everybody's gasoline, enough information was secured to plot a chart showing the amount of dilution to the percentage of iron taken out of these used oil samples.

Some think that the condition does not warrant very much thought. If it is necessary for a lubrication engineer to lubricate a piece of machinery that requires an oil of 300 Saybolt sec. viscosity and he has to use an oil of only 45 Saybolt sec. viscosity at 100 deg. fahr., which is practically gas oil, he would know that the oil was entirely too thin to support lubrication. Under forced feed to the bearings lubrication probably can be supported down to that degree of thinness; but, with the cylinder walls and the grooves and the surfaces of the piston-rings, points which affect the economy of the engine as to the leakage of the gas as the oil gets thin, we can expect greater consumption of oil and gas and more wear. The wear can be determined by taking samples of oil and examining them for iron. Charts for the same car show that as the weather temperature increased during the week the wear decreased, because the oil became thicker and prevented abrasion. As the weather gets colder, dilution increases; the oil holds more of this diluent, up to 50 per cent, and the law is established that as we increase the dilution we increase the wear, which is indicated by the amount of iron taken out of the samples.

The tendency of these curves merits some consideration. Oil is at its best on a forced-feed system when the oil is thin enough to just keep the surfaces apart. As indicated by the temperature of the bearings, the friction is much less with the thinnest oil. Therefore, dilution and the thinning of a thick oil with heat increase the efficiency of the engine by reducing the mechanical friction load. That is, when starting a machine, the frictional power is the greatest with cold oil and the curve comes down as the oil becomes thinner through heat and through dilution.

There is a condition, however, which the oil reaches where it will not support lubrication and abrasion takes place. That point is changing constantly on the cylinder walls and in different places not under forced feed. Gradually, the area where abrasion takes place increases as the oil becomes thinner and will not support lubrication or keep the surfaces apart. It is natural to suppose, if dilution is increased in an amount necessary to make the oil too thin to support lubrication, that then we will have a gradual increase of frictional power. The effect of fuel upon the lubricant brings about general rules of lubrication which are entirely the result of the practical observations of many people.

The German aviation service used a lubricating oil of

750 Saybolt sec. universal viscosity at 100 deg. fahr. and about 54 Saybolt sec. viscosity at 212 deg. fahr. for their Zeppelin engines and for the entire aerial machinery during the war. The French and English used mixtures of American oils much thicker in average body. In the American Air Service we used oils materially heavier, and many of our aviators thought they must have something much thicker than we were disposed to give them. The engines of all three services were practically interchangeable. They all presented about the same lubrication problem; yet the German service, for about 5 years, used oil that we could not use in the American engines because it was too thin. The reason these three services demanded and required different kinds of lubricating oil for practically the same machine is traceable to the fuels they used. Germany had more volatile fuels for its aviation service during the war than any other country. The oil the Germans used became heavier in the engine, as we could determine very well from airplanes that were shot down from time to time. The French had fuel that was less volatile than the German fuel and we had to get along with fuel of still heavier end-point; consequently both American flying machines and those of the Allies required heavier lubricants to offset the dilution effects of the heavier fuels.

There is little use in presenting a serious problem unless some solution is offered. Before considering what can be done to solve this problem, we must answer some of the statements made by a number of men engaged in the oil industry that crankcase oil dilution conditions cannot be serious because they have not been called to their attention. One large motor-trucking company has concluded from its records of the year just past that 85 per cent of its engine service jobs are traceable to lack of lubrication due to this dilution problem. That percentage has been confirmed by three of the large producers of motor trucks. The motor-truck service people evidently know more about this problem than we are willing to confess we know. We know of the demands made for heavier oil, which should show us what is wrong. The motor-truck people have the impression that the condition can be overcome to some extent by draining and replacing the oil about twice as frequently as is now recommended in their instruction books. One difficulty is that dilution sometimes occurs to the full extent, on a cold day, within the first hour of the first day or the first 50 miles; so, if automotive engineers issue general instructions that oil is to be drained as soon as dilution takes place to a certain degree, our motor-truck drivers will spend most of their time under the trucks. Frequently draining the oil will undoubtedly have considerable cleaning effect on the engine, but it will not prevent dilution. The industry was actually short of heavy engine oils during 1920. Using more oil per 1000 car-miles in an attempt to overcome dilution will bring about a shortage without materially improving conditions unless an immediate reform is made in the practice of throwing used oil away.

In the American Air Service, reclamation stations for the reuse of aviation oil were established. For 4 years preceding the period of our entering the war, the Allies and our enemies were using oil in their aviation engines and, at periods of about 5 hr., taking it out and throwing it away because the oil was supposed to have become worn-out. Dilution was not a problem because of the grade of fuel used, the oil was heavy, and produced much carbon, and after 5 hr. as a rule became so thick that the pumps would not handle it.

Considering the number of engines that the United States Air Service expected to build and operate, according to our factor of consumption of oil per horsepower-hour, there was not enough oil in the country to support the program. Our supplies had been depleted by the extravagant method of the Allies in operating their machinery during the war period. It was necessary to institute a reclamation program and, against the advice of a large number of refiners, this was done. Many believed that it would not be possible to reclaim oil that had been used in an aeronautic engine, bringing it back into a condition that would make it suitable for such use again, but the possibility of reusing a vast amount of oil was great enough to encourage us to institute the program.

Oil Reclamation Method

The system was very simple. We put the oil and water into steam-jacketed tanks and blew steam in; soda ash or "gold dust" was sprinkled on the surface of the oil, thus forming emulsions and obtaining a precipitation of carbon, iron and dirt, after a period of rest. In an hour or two we obtained clean but black oil. The steaming had removed the 2 or 3 per cent of the diluent that came from our volatile aviation gasoline. The recovery of good oil in extreme cases was as high as 85 per cent and for 5 months we obtained a 75 per cent recovery of 50 per cent of all the oil used in the Air Service. The other 50 per cent was burned in the engines. If the war had continued and we could have installed oil-reclaiming stations in Europe, we would have had the equivalent of many refineries right back of the battle front.

If we should reduce the end-point of the gasoline to help the situation, which would mean reducing the amount, in a year or so we would be forced by the demand for fuel into exactly the same situation that is facing us today. We can reduce the actual fuel per brake-horsepower hour required by these engines if we force new clean and cold oil directly where it is needed to preserve the sealing required to prevent leakages, but we cannot supply such a system to the present 10,000,000 engines. In his paper on Dilution of Engine Lubricants by Fuel,[1] G. A. Kramer recommends a device for the restoration of engine oil that can be attached to the engine. Such a device has been designed. It will treat the oil in the engine, bring the oil back to its original body, allow the use of originally thinner and cheaper oil, recover the fuel vapor and put it back into the intake manifold. I have seen one such device that looks extremely interesting. It consists of a small reclamation plant under the hood that is no larger or more complicated that the vacuum fuel system. Reclamation apparatus should be installed wherever there is a fleet of trucks. The reclamation apparatus manufacturers are engaged in an attempt to develop apparatus that can be used generally. For the future and to care for the engines already built, the dilution problem must depend for its solution upon apparatus that can be attached to the engines to remove the diluent and reclaim the oil and upon frequent removals of oil from other engines, such oil to be passed through recovery stations so that it can be reused.

Chairman H. M. Crane:—The automotive engine was first designed to make use of a dry fuel. I probably was one of the first users of gasoline in this country, as I operated about 1887 a naptha stove for which we bought

[1] See The Journal, February, 1920, p. 123.

stove gasoline or stove naptha for 10 cents per gal. Gasoline was a by-product in those days.

We have reached a condition now in which we are not operating with dry fuel but with an absolute liquid in the cylinders. This has changed the problem entirely and I feel nearly as helpless as Mr. Parish does regarding the situation, in view of the large number of cars which are being operated. As an automotive engineer I do not wish you to believe that I think these cars are perfect or anything like it. They are representative of bad design in many ways, and of very inferior construction, which is even worse. If the whole secret of developing power lies in the type of piston and cylinder, according to our aviation experience, there are hardly any cars in existence today that are properly constructed. They can be properly constructed. We had occasion to overhaul a car that was delivered to its present owner in 1912 and has been driven commercially in the owner's service with the oil and gasoline that his chauffeur bought. An examination of the pistons and rings in that car indicated that the exact clearances that were built into the engine in 1912 still existed. The cylinders were 4.375 and the pistons 4.372 in. in diameter. The reason was that the pistons were extremely long, and were properly lubricated. That engine is in use with the same manifold and the same heating devices that it had originally and, so far as we know, there is no great trouble; there is certainly not enough to influence dilution because, after 44,000 miles of operation, we did not find it necessary to disturb the adjustment that was built into the car in 1912. That is an example of what can be done with good workmanship and good material; but it cannot be applied to the cars now outstanding. The same thing is equally true regarding the addition of such things as the pressure oil feed to the cylinder walls. That undoubtedly would be a great help to the cars that have cylinders that are not round or straight, or pistons and rings that do not fit.

One of the difficulties in the early days was to make the piston pump things down and not up. That is, the oil was fed, for purposes of simplicity, in such a way that it was drawn up instead of down and reached the upper end of the piston. The result was that in all designs of pistons, rings and other details, they were made with the object of pushing the oil back again. That was fine so long as we had to deal with nothing but the oil, but now we are dealing with the liquid part of the fuel that is fed into the cylinder. We cannot distinguish between the liquid part of the fuel and the oil and we get the conditions that Mr. Parish has described. This may require an entirely new scheme of oil feed, but it is all a part of the question raised by the use of heavy fuel. During the war we started with the design of an engine to run with castor oil. The use of castor oil was one of the reasons for the rapid change in the engine that was noted by pilots in the service; that is, castor oil is a very fine lubricant of the machine, but it resembles linseed oil in that it oxidizes and becomes very thick and gummy. We could see no reason for using castor oil. We happened to be using for similar work a mineral oil of about the same viscosity as castor oil. That oil, in 1916, was a commercial and not a special oil. We did not have it manufactured to suit our own ideas of the oil needed. We kept on using it, and we were testing our own engines with commercial motor-car gasoline. Mr. Parish's work during the war caused him to believe that there was not a sufficient supply of oil of that high viscosity, and he determined the Liberty oil specifications, which were 85 Saybolt sec. I think, at 210 deg. fahr. Finally, the time came when we were asked by the Government to use Liberty oil for lubrication during our tests. We made tests of it, which exactly bear out what Mr. Parish stated with regard to the use of oil in Europe. We stated that if we used commercial gasoline, we would have to use thicker oil to protect the pistons and cylinder walls and, if we attempted to use motor-car gasoline with Liberty oil, we would have an excessive loss of engines during tests due to scored cylinders, or we would have to extend the running-in time of those engines to double the ordinary period to arrive at the same result. As each engine we were testing was using from 50 to 70 gal. of gasoline per day and toward the end we were building 60 or 70 engines per day, although they were using only 1½ qt. of cylinder oil per hr., it seemed to me better to use the gasoline of the lower grade in greater quantity, rather than the oil of the lower grade in greater quantity; that was my idea of economy at that time.

Dr. Dickinson, of the Bureau of Standards, has done much interesting work on aviation engines during the war, and also on various types of car engine. He finally determined to make a study of what actually occurs in the fuel-feed system of an engine. Many of us have thought we knew what occurred, but nobody had actually seen it. He succeeded in making a glass manifold of a type of glass that would resist heat, and in actually taking motion pictures of the fluid flowing through the manifold. I say "flowing" very advisedly, because that is what it does. It is interesting to witness visually what Mr. Parish has described as the cylinder conditions in the engine; that is, that the cylinder is not now fed with a dry mixture at all, but with a mixture of air and liquid.

One of the handicaps that automotive engineers have met in their own industry in promoting economy and conservation of fuel has come from the commercial point of view. It is a perfectly fair point of view, that if the public are satisfied with what is being given them, that is the answer. I think we cannot say that this view is not right in ordinary commercial activities. Two of the largest builders of automobiles in this country are found in that class. The public continues to buy their product in large quantities, they have not seen any reason why they should improve it in gasoline consumption and they are by far the largest users of gasoline.

On the other hand, this is not a commercial problem at all. The problem is whether we are going to have any industry, either an oil or an automotive industry, within a few years; in view of this, the automotive engineers feel that they cannot wait until the public demands improvement. We must try to obtain improvement before the public demands it. I hope that the oil men will feel that when we come to them with our problems we are coming with that point of view. We trust that they will feel that the apparent satisfaction of the public with the gasoline they are receiving is not necessarily the final answer; that, if by cooperation the engineers of the two industries can get a greater ton-mileage per year out of the gasoline supply, it is something that ought to be done. I will say for the Society of Automotive Engineers that we will go to any extent that we can in aiding improvements in every direction in our own use of fuel and in cooperating with the petroleum industry as to the best and most economical type of fuel for the various types of work that we have to do. I hope that the oil men will come to us in the same way and put their side of the case before us, and if we do not understand it, persist until we do understand it. I think many of us

do understand the difficulty of meeting the excessive demands for fuel at present, and we must realize that the great American public has never been accustomed to conservation. If our two industries can educate the public to be more careful in its use of fuel and to get more good out of what we provide, we certainly ought to do it. We do not try to get the public discontented with what it is getting from the oil industry and I think the representatives of the oil industry do not try to get the public discontented with what it is getting from the automotive industry. We do not want to start the public off on any line of demand that we do not know in advance can be reasonably met. That is why it is so important for us all to get together and find out now if we can, and certainly as soon as we can, what is the best line for the two industries to follow in cooperation, toward the result we all want to reach.

R. D. LEONARD:—Our figures indicate that, so far as gasoline consumption is concerned, of the 7,000,000 automobiles in use approximately 6,000,000 are passenger cars and 1,000,000 motor trucks; and that the trucks are using approximately six times as much gasoline per unit as the passenger car? That means that the consumption of gasoline in the country is practically equally divided between motor trucks and passenger cars.

I have gathered from Mr. Parish's remarks that the dilution problem, so far as the end-point of gasoline is concerned, is intimately associated with the viscosity of lubricating oil. As the end-point of gasoline goes up, the viscosity of the oil used must be greater. Our tests indicate that a motor truck uses about twelve times as much oil as a passenger car. In all the samples of crankcase oil that we took from our trucks we did not find a very high percentage of "volatiles"; the average was not in excess of 5 per cent, which was conceded to be not very detrimental. Does the automotive industry recognize that the problem of the motor truck is different from that of the passenger car in this respect?

CHAIRMAN CRANE:—There is no question that the problems are different, and that the automotive industry recognizes them as being different. The use of the greater amount of oil in the truck as compared with the passenger car is explained by the more intensive service of the truck. The truck engine is loaded to a far greater percentage of its total horsepower capacity per hour than the passenger-car engine is; in fact, the latter, as it is used in this country, very rarely reaches one-third of its maximum capactiy. That also applies to engine revolutions. The normal passenger-car engine runs from 500 to 700 r.p.m. as against a truck engine running from 1200 r.p.m. up. That can be determined by comparing a Ford truck with a Ford touring car. The ratio is nearly 2 to 1. That is the reason for the excessive use of lubricating oil, comparing the two jobs. The larger proportion of passenger cars are laid up in the colder months. On the other hand, the truck is nearly 100 per cent an all-the-year-around vehicle and for that reason experiences difficulty in winter, when the greater amount of trouble with the dilution problem is experienced. The trouble comes almost entirely in starting in cold weather, when an amount of gasoline up to three or four times that required in normal running is necessary to produce an explosion in the cylinder. The main point in regard to the truck engine is that it is used far harder than the passenger-car engine, and therefore requires more oil.

MR. LEONARD:—Does that modify the dilution problem itself? When adding fresh oil, one is adding all the time to the viscosity.

CHAIRMAN CRANE:—Certain cars today lose oil so fast that dilution is no problem at all. That is, they do 250 or 300 miles per gal. of lubricating oil without dilution; to cars of that class dilution is no problem whatever. There is no excuse for any passenger car doing less than 1000 miles per gal. of cylinder oil.

E. PLANCHE:—The engines used in trucks are much larger than the engines used in passenger cars; consequently they require more oil.

CHAIRMAN CRANE:—That is another way of saying that on the average they are developing more power.

H. L. HORNING:—In the motor truck the load factor is 2½ times as much as in the motor car. The motor car will skim along the road at 15 per cent of its maximum power and some do better than that. With the truck, one thinks of it as being around 40 per cent at the speed at which it usually travels. This means that the truck piston and the truck crankcase oil are at a higher average temperature because of both the load and the speed. One of the factors that is very little recognized today in the design of motor cars and trucks is that bearings cannot be maintained in a truck unless the crankcase bottom is exposed to the air passing by it. That is also very largely true in the case of the tractor. It is a very important factor in keeping the oil cool. With the higher temperatures of the piston, the viscosity of the oil is reduced and therefore its use must become affected.

With motor car engines much attention is given to smooth running. With truck engines the tendency is for a demand to be put upon the driver for results. The driver then does the next best thing; he throws fuel into the system; the fuel has a tendency to break down the lubrication oil. That has nothing to do with the relative fuel consumption of the vehicles, because that is based on factors outside of those considerations. The obvious way to cut down lubricating oil consumption is to vaporize the fuel better.

If there is any special defect in our cars, trucks and tractors, it is that we fail to prevent leakage from the carbureter to the exhaust. That means no leakage of air between the carbureter and the intake manifold; none between the intake manifold and the cylinder, or in the intake-valve guides; no leakage of the valves into the combustion-chamber; none past the rings and pistons; and, lastly, no leakage past the exhaust valves. When we accomplish this, the economy is remarkable.

CHAIRMAN CRANE:—During the war we started building an engine of 150 hp., running 4-hr. tests at about 1500 r.p.m. The engineering development department did much experimental work on the same engine with possibly 15 per cent higher compression, which gained a very considerable amount of horsepower. We were finally ordered to put that engine into production. The shop brought the engines out and put them on the test-stand and every engine failed, without exception. The pistons were blown by and often holes were blown through the top. They were aluminum pistons. We found that the piston and cylinder job that was tight enough for a 4.75 to 1 was not tight enough for a 5.35 to 1 compression ratio. The leakage and the heat that goes with it increase somewhere between the square and the cube of compression ratio and the explosion pressure which follows. The result was that the pistons were being overheated and the oil in the cylinders all broken down by the waves of heat. They found they could make the pistons tight, and when they made them tight there

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Variable Factors in Highway Design

By H. Eltinge Breed[1]

Annual Meeting Paper

THERE are two factors in transportation, the vehicle and the road. When transportation falters, each factor blames the other; the roads fail because the vehicles punish them too hard; the vehicles are impeded because the roads will not sustain them. So recrimination rounds the vicious circle, and we end where we started, in worse temper. Self excuse and shifting of blame only block transportation. To solve the problem we must work together, recognizing our mutual dependence. It is to the interest of automotive engineers to design vehicles that will afford the maximum transportation facilities with the minimum wear upon the roads; it is equally to the interest of highway engineers to design roads that will give the maximum transportation service at a minimum cost both to themselves and to the vehicles that use them. When, together, we have achieved that end, we shall have provided this country with a really adequate system of highway transportation.

If prospective traffic, soil conditions, drainage, surfacing, maintenance and politics were definitely known quantities instead of algebraic unknowns of more or less intense degree, then our problem would be simple, you would proclaim the glory of our roads, and we should hail the latest Leviathan in motor trucks as an object of supreme affection. Those conditions are not constant, however; they are variable. We can measure them at present only by empirical generalizations; what has happened before under similar conditions will probably happen again. To apply that slippery gage so as to secure uniform success requires unusual experience and ability, and even then a cog slips occasionally. Neither ignorance on the engineer's part, nor carelessness or fraud in construction is the cause of many of the failures; the variable factors involved simply defied the best opinion and practice obtainable.

Type of Pavement

Of the six factors, or variable conditions that I have mentioned, I shall speak of four but very briefly. It is on the other two, the first and last, that we can cooperate to secure better transportation service. In designing a road the first thing to be determined is the type of pavement to be laid. Although cost, soil conditions, availability of materials and other considerations influence the decision, the real factor that determines it is the volume and character of the traffic which will use the road. Because this traffic is problematical, the choice of pavement must be empirical rather than strictly scientific. We know that the heavy traffic around large cities demands the strongest and best types of pavement, and that in sparsely settled, non-industrial regions, we are safe in designing a semi-durable type, but in the whole wide field between these extremities, money, time and energy can be wasted either on over design at costs disproportionately high for the transportation service rendered, or on design that is so inadequate to the prospective traffic demands as to make failure inevitable. How can we design for this prospective traffic? We all perceive now the futility of the old traffic survey in helping us determine the type of pavement. Because only 10 motor cars travel today over the mud road between Alpha and Omega is no guarantee that only 100 motor cars will travel over it daily after the road has been improved. The problem is more complex: How much tonnage of all kinds, carried by all transportation agencies, is now consumed and produced daily by all the communities the road will serve? Then, how much of this tonnage is the motor truck able to haul? For it is fair to assume that, once the road is improved, all that can be transported by motor truck will be. Last, what is the probable growth of the communities in question, according to the latest United States census, with the increase per capita in goods consumed and produced? Given this freight haulage, the actual passenger traffic over the road is a corollary of minor importance. Let us know the prospective freight tonnage for which we must design, and we shall have a much more definite basis than any we have today upon which to decide our type of pavement.

There is one way in which we can cooperate in securing and preserving adequate pavements. We are all fairly well agreed now that the greatest damage done to roads is by impact, that is by the pounding of the load upon the road. This pounding is accentuated by any unevenness in the road itself or in the tire of the vehicle. There is the rise, the jolt, the drop of many tons weight upon the same spot over and over again and the gradual, inevitable shattering of the pavement, a little more at each blow. Many studies are being made about impact which will help us in the design of our roads, but this much we all know now from experience; a perfectly smooth tire on a perfectly smooth road affords no impact. It does not pound; it rolls, and the only wear is the negligible attrition caused by a smoothly rolling load.

We are trying to perfect a durable, firm pavement whose surface shall be as smooth, though not as slippery, as a starched shirt front. Can we, as highway engineers, depend upon the automotive engineer for the tires? Part of the tire trouble, we know, is due to the carelessness of motor-truck users and must be overcome by education in which we can both take a part; the automotive engineer for the preservation of the trucks and the highway engineer for the preservation of the roads. These are the significant facts about the relation of tires to roads; the smoother the tire, the less the damage from impact; the broader the tire, the more diffused is the weight of the load over the bearing power of the road. We ask your help in respect to smooth, broad tires and in the other matter of educating motor-truck users. The man who overloads his truck beyond its capacity is a public nuisance, and a renegade to your interests and ours. We cannot flay him, so he must be taught to keep within bounds.

Foundation, Drainage, Surfacing and Maintenance

Other variable factors in highway design which are perhaps so technical as to be of especial interest only to highway engineers are foundation and drainage. Briefly put, our problem is this; the stability of the soil determines the strength of the foundation we must use. This stability varies inversely with the moisture content, the more moisture the less stability, and consequently the greater strength of foundation required. How can we

[1]Consulting engineer, New York City.

determine accurately the moisture content? We cannot! At present there is no definite gage by which to measure it. It varies according to the geological formation, the character of the soil and the season of the year. We only know approximately, from an examination of the roadway under discussion in the light of former experience with similar roads, just what strength of foundation will be necessary to sustain a pavement permanently. We can only estimate what drainage is necessary to take care of an unknown amount of water. Even on the same road, the design for the foundation should, I believe, vary if at one or more places the moisture content at the driest season is greater than it is in other places at the wettest season. It is economy to put the stronger and more costly foundation in the moisture-laden sections, and to build the lighter and cheaper foundation where the dryness gives a stability of soil that precludes a breakdown. The same principles apply to drainage, but in the final analysis, questions of foundation and drainage are answered by the personal opinion of the engineer, and upon him, at this point, depends the fate of the road and of the taxpayers' money. The investigations now being conducted about foundations will, I hope, afford us a more scientific basis for procedure.

Two other variables that affect our transportation system are surfacing and maintenance. The latter, largely beyond the power of the designing engineer, connects directly with the last point I should like to make, the effect upon our highway systems of political changes.

The variability in surfacing is apparent to the casual observer. Two pieces of pavement are built according to the same specifications, contiguous to each other, under exactly the same soil and climatic conditions. Yet one of those pieces is 90 per cent good; the other 50 per cent bad. The difference lies in the variation in human nature; one contractor uses scrupulous care in the selection of materials, safeguards the blunders to which the workmen are liable and himself supervises the proportioning, mixing, placing and finishing of the pavement. The other contractor shirks personal supervision, is lax in inspection of materials and depends upon lazy, indifferent or incompetent workmen. Ultimately, the former succeeds and the latter fails, but not before he has squandered our money and inflicted upon us miles of bad pavement. It is, of course, the function of engineering supervision to safeguard the public from the incompetent contractor, but although good supervision will prevent the most flagrant blunders or frauds, it cannot wholly offset the weak contractor's tendency to produce poor work.

Politics in the Highway Department

Back of much construction work lies the second main point on which I believe automotive interests and highway engineers might effectively cooperate. I refer to the political domination of highway construction and maintenance. Having been part of the highway system in New York State for 13 years, and having been out of it a sufficient time to place what I say beyond any suspicion of personal prejudice, I do condemn, in the strongest terms, the custom of making the development of our highway systems depend upon the turn of the political wheel. To develop the highway systems in the various States requires men at the head of each highway department whose tenure of office is secure; who are expert engineers knowing highways from the sub-base up and beyond; who care not one whit for political preferment, nor are in one whit dependent upon it; whose sole interest it is to do the work assigned to them and thereby give this country the basis for a transportation system that shall be a pride to the builders of roads, the builders of vehicles and the users of both.

As it is now, with every change of political administration, which occurs every two or four years, there is a change in the personnel of the highway department. New men come into power, men often entirely inexperienced in highway work. A shopkeeper, whose wildest reckonings have been in terms of thousands is suddenly called upon to control the expenditure of millions. Is it any wonder that he falters and is easily imposed upon? Or that his subordinates spend months in discovering what their jobs require, months more in learning how to do them and the remaining months in preparing what to try next, after they are ousted?

The evils of the system are apparent; lack of adhesion to any coherent, continuous plan; lack of a sense of responsibility beyond the glimmering hope that there will be as little graft as possible, and that that little will escape the attention of the opposite party; the apportioning of jobs and even the locating of roads at the dictation of political potentates and the passing of snap judgments on insufficient knowledge about important policies.

Generalizations are easier than a detailed study of cases. Hence if the outgoing incumbents have held that to please the public one must build many miles of road, no matter what kind, then it is highly probable that the incoming incumbents, moved by the storm of public protest against the premature disintegration of new-born roadlings will say, "We build for permanence; fewer miles, but better." So we get a patchwork of extensive poor roads and of limited good ones imposed and usually without discrimination about the needs of the special locality they are to serve.

Happily, there is even in this politics ridden era a type of commission that tries to apportion its money to best advantage, with the durable, more costly roads where they are most needed, and the cheaper, less durable types where the traffic is scant. But when one sees a fine brick pavement that would be a credit to a town, built where it leads nowhere, one becomes depressed. We need completed systems, not costly spurs.

There is no reason why roads should be dominated by politics. If influential bodies like this Society would combine to rouse public opinion, changes could be made in the highway laws that would permit the securing and retaining of competent men, preferably experienced highway engineers, in charge of the work. Then through the control of these first and last variable factors we might hope to accomplish speedily and economically our mutual purpose of giving this country, large as it is, the best transportation system in the world.

The Packard Fuelizer

By L. M. Woolson[1]

Cleveland-Detroit Sections Paper *Illustrated with* Photographs and Diagrams

To present in the proper light what the Packard fuelizer is and how it performs its functions, it is advisable to consider briefly what the general requirements are for ideal carburetion under varying conditions. Let us consider first the basic engine such as is shown in Fig. 1. There are three main elements of the design with which we are concerned; the carbureter or fuel-metering device, the manifold, and the combustion-chamber. Each of these elements has its particular functions to perform. The carbureter must furnish a suitable mixture over a wide range of speeds and loads; the manifold must distribute this mixture in a suitable condition and in a uniform manner to the various cylinders, and the combustion-chamber must permit complete combustion of the fuel. None of these elements can perform the functions of another; if the carbureter does not produce the desired mixture the manifold cannot deliver it to the cylinders, and if the manifold does not deliver a uniform mixture to the different cylinders, conditions in the combustion-chambers naturally will vary.

Considering the carbureter first, this has been developed gradually to a point where reasonably good operation is assured, and the metering characteristics are sufficiently accurate for practical purposes over a wide range of conditions. The average carbureter, if properly adjusted, will deliver a 15 to 1 substantially constant mixture, or whatever may be desired, under all ordinary running conditions. There is much work to be done in making the carbureter produce the varying mixtures actually required for the most efficient operation of the engine under varying conditions. However, at present we are concerned with the supply of a mixture of air and gasoline maintained at practically a constant ratio under varying load and speed, and in this respect the modern carbureter can be considered satisfactory.

It must be admitted that manifold design has been largely a matter of trial and error. There are a few well established rules to follow but, in general, we build the manifold first and fit a theory to it afterward. Almost any design of manifold will deliver a mixture of gases in a very uniform manner to the several cylinders, but when we attempt to distribute a mixture of air and liquid gasoline particles we find it extremely difficult to obtain uniform distribution. The gasoline particles can be considered as occupying the relative space shown in Fig. 2. Their volume is only 0.01 per cent of the volume of the air in the manifold. Furthermore, their weight for a given volume is about 560 times the weight of the same volume of air, with a correspondingly greater inertia. Therefore, it is not surprising to find that, if the gasoline is in the manifold in a liquid state, uniform distribution is practically impossible. Gasoline is not an homogeneous substance with a fixed boiling point, but is of a very complex nature and various fractions of it boil at various temperatures. Furthermore, the fuel will be broken up mechanically to a greater or less extent, dependent upon the jet construction and the atomizing means, if any, which may be employed; so, the manifold is called upon to distribute a mixture of gasoline and air which has practically the same chemical composition for all carbureters. The physical structure of this mixture depends, however, upon several variables; but, in general, the mixture, as delivered by the carbureter to the manifold, is at best merely a spray of liquid gasoline mingling with the air current.

We find a great variety of designs of combustion-chamber, dependent largely upon the valve arrangement; the L-head, T-head, overhead and F-head arrangements, each of which produces a combustion-chamber with a certain characteristic shape. The behavior of the mixture of gasoline and air after entering the cylinder is determined to a certain extent by the shape and design of the combustion-chamber. Generally speaking, however, the troubles which the fuelizer was designed to overcome are common to all forms of combustion-chamber. There is, however, much to be done in combustion-chamber design to eliminate or diminish detonation, which in itself represents a large field for study. This point serves to bring out again that each of the three elements of the engine which we are considering has its own problems. Detonation is largely a matter of combustion-chamber conditions and is related only indirectly to manifold conditions.

Uniform Distribution

It is difficult to secure uniform distribution with what we term a wet mixture. There are two other main reasons why wet mixtures are undesirable, especially when the engine is working on part throttle under reduced load, as is the case in automobile practice fully 90 per cent of the time. First, spark-plug fouling has been found to be brought about almost exclusively by wet-mixture conditions. It has been shown that an excess of lubricating oil in the combustion-chamber is not responsible for fouled spark-plugs, as was commonly thought. In fact, if an engine is supplied with a dry mixture, the spark-plugs will continue to function in spite of an excess of clean oil that may be present. We hear often that some engines pump oil in certain cylinders and foul spark-plugs by so doing but, as a matter of fact, experiments have shown that this is merely a mixture condition associated with poor distribution. It is the end cylinders of an engine that will be said to pump oil and foul spark-plugs as a general rule. The reason is that, in nearly all manifold designs, there is a tendency for the heavy gasoline particles to continue in a straight line to the end of the manifold. There they turn in and thus bring about these spark-plug fouling conditions. There is also the problem of the dilution of the lubricating oil by so-called kerosene, which is a familiar condition. This has been considered formerly as a cold-weather condition only, but many cars are bad offenders in this respect in even moderately warm weather. I believe that these facts are

[1] M.S.A.E.—Experimental engineer, Packard Motor Car Co., Detroit.

recognized universally at present and that the desirability of a dry mixture, at least for part-throttle work, is self-evident.

Many methods of supplying the requisite amount of heat to the intake manifold have been tried. The use of heat from the exhaust gases has been favored recently, and many schemes have been evolved with the idea of concentrating the heat where it will do the most good. I will not attempt to discuss these various devices in detail but will state that the fuelizer was evolved only after several different types of exhaust-heated manifold had been tested and found wanting in some particular or other. The trouble was not that there was insufficient heat available in the exhaust, since the exhaust may contain from 25 to 50 per cent of the heat units obtainable from the original fuel. As a matter of fact, considerably less than 5 per cent of the heat contained in the fuel which the engine is using is required for vaporizing purposes. The main point has been that the exhaust heat is represented by a comparatively large volume of gas at a comparatively low temperature, and what is required for the efficient application of heat to an intake manifold is rather a limited amount of gases at very high temperatures.

Another reason for this latter requirement is that it involves a very simple means of regulating the heat in accordance with the work the engine is performing. As is well known, the volumetric efficiency of an engine is dependent upon the weight of the charge drawn in, and it is obvious that if we heat the charge it will expand. A given volume of the heated charge will weigh less than the same volume of cool charge; consequently the output of the engine will be decreased in proportion to the temperature rise of the mixture. The extent of this loss in volumetric efficiency can be judged when we consider that for each fahrenheit degree rise in temperature there is a loss in weight for a given volume of about 0.2 per cent, so an increase of say 100 deg. fahr. would mean a loss in output of something like 20 per cent.

Detonation

There is another serious disadvantage in maintaining the mixture at too high a temperature under wide-open-throttle work. This is in connection with the phenomenon of detonation, which has been recognized only lately to be the cause of what is familiarly termed "spark knocking" or "spark hammering." When a charge is ignited in the combustion-chamber, the flame propagates in all directions from the point of ignition and, if the engine is working on full throttle, it may happen that some of the charge will be so highly compressed by the advancing wave of flame that it will detonate. The momentary pressure due to detonation may be three or four times as great as the pressures brought about by more gradual combustion. There are many factors influencing detonation; the general shape of the combustion-chamber, the location of the spark-plug, the compression ratio, the extent and thickness of the carbon deposit upon the combustion-chamber walls and piston-head, the temperature of the jacket water and temperature of the incoming charge. It will be seen readily that if the temperature of the incoming charge is greater, a proportionately larger amount of highly-compressed unburnt-mixture will detonate.

The theory has been advanced that, within reason, the higher the temperature of the incoming mixture is, the better the fuel efficiency under wide-open-throttle conditions will be. However, this has not been borne out in practice. The Bureau of Standards has confirmed this

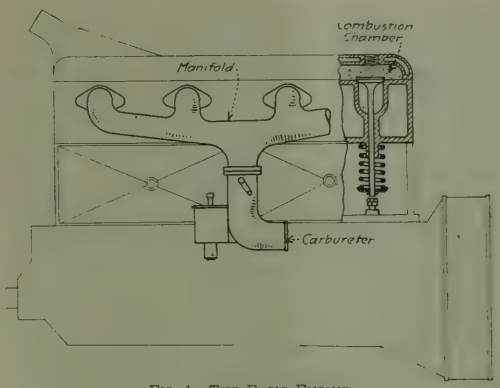


Fig. 1—The Basic Engine

by recent tests which show that, when running wide-open, there is very little if any connection between fuel economy and mixture temperature. In the matter of acceleration, however, a paradoxical condition prevails. Although we have seen that volumetric efficiency falls off with increase of mixture temperature, it is true that the accelerating quality of an engine is very much improved by an increase in mixture temperature. This also has been confirmed by some recent Bureau of Standards' tests. I have driven cars with mixture temperatures exceeding 400 deg. fahr. which had extremely good acceleration. However, when a hard steady pull up a steep grade or through heavy going is required, a cool mixture gives by far the best results, owing to the improved volumetric efficiency. Incidentally, there seems to be no disadvantage in using relatively cool mixtures under wide-open-throttle conditions. This is no doubt due partly to the high temperatures prevailing in the combustion-chamber and on the piston-head and, as is well known, spark-plug fouling and crankcase dilution are not ordinarily associated with wide-open-throttle work. Accordingly, we find that the following rules apply as to the most desirable mixture temperatures to be maintained:

(1) For idling, fairly high temperatures are to be attained as quickly as possible after starting, to avoid loading, spark-plug fouling and crankcase dilution
(2) For slow running on part throttle, an equally high temperature is desired. Very good results for this work are given by a temperature of 180 deg. fahr.
(3) For accelerating, a similarly high temperature is desirable
(4) For continuous wide-open-throttle work, the lower the temperature is, the greater the power will be; although a mixture temperature below 100 deg. fahr. with present-day gasoline is not advocated. This is merely a concession to good distribution

As to why distribution under wide-open-throttle condi-

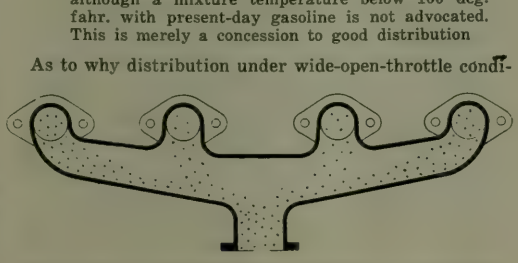


Fig. 2—Diagram Showing Mixture Conditions in the Manifold

tions does not demand an equally dry mixture, as has been stated was desirable for low-throttle work, practical experience with many types of engine has shown that in every case good distribution can be obtained with proper manifold design and without supplying more heat to the mixture than can be supplied through the water-jacketed passages which are commonly integral with the cylinder. This is substantiated by fuel-consumption tests such as were conducted by the Bureau of Standards, with the mixture at various temperatures. This condition does not necessarily apply to lower-grade fuels such as kerosene. I believe we have an insufficiently thorough theoretical knowledge of distribution to prove this point, although we know that with the increased mixture velocities met with in wide-open running there is less tendency for the liquid particles to separate from the air-stream and condense on the manifold walls. It is this condensation or deposition that is responsible for poor distribution of wet mixtures with low mixture-velocities. Then again, under a wide-open-throttle condition, the increased compression pressures, the higher temperatures of the combustion-chamber walls and the increased turbulence all assist in carrying out the combustion of a wider range of mixtures than would ignite under less favorable conditions.

Ignition

The source of the ignition spark for the fuelizer is an important element in the device. There are several different ways of securing the necessary current but, as a result of experience, certain methods have proved the most desirable. With battery-ignition systems, a separate low-tension breaker can be used in conjunction with a standard ignition coil. The secondary winding is connected directly to the fuelizer spark-plug. This plug is of special construction only in the electrode arrangement. A wide gap has proved to give the best results, the gap used being about ⅛ in. It has been found also that the amount of spark heat is of considerable importance, especially when starting up in extremely cold weather. In this respect the requirements are very similar to those demanded of the engine ignition system and, in general, the same type of coil windings can be used for both engine and fuelizer ignition service. If it were desirable to limit the current consumption to a minimum, a special coil having many more primary turns could be built for the fuelizer. The increased self-induction would result in a poorer spark at high speed, but this would not affect the fuelizer operation materially, since its main purpose is to supply heat at the lower speeds. Another method of securing the fuelizer spark consists of bringing out the inner end of the secondary winding of the regular ignition coil. Normally, this terminal is connected to ground either directly or through the primary winding. It is believed that such a method does not represent good practice, since the wide gap of the fuelizer plug offers considerable resistance when the throttle is wide-open. Under these conditions the compression pressure in the cylinders is at a maximum and therefore the resistance of the entire secondary circuit, including both the engine and fuelizer spark-plug in series, would be excessively high. Another method is to connect two ignition coils in series with a single breaker. One of these coils is connected to the fuelizer and the other to the engine ignition distributor. A fairly good result is attained in this way, provided the different elements of the system, such as the cam contour, the condenser and the coil windings, are suitably proportioned.

When magneto ignition is used, a special magneto is required. For four-cylinder installations, several types of five-spark magneto are available. In one type the rotor and interrupter are of eight-cylinder design, four sparks per revolution of the rotor being produced. Two of these go to the engine spark-plugs and two to those of the fuelizer. This system permits using only the negative sparks for engine ignition, which has certain advantages from the standpoint of spark-plug-electrode life. Another means of obtaining a magneto spark for the fuelizer is insulating both ends of the secondary winding, which is commonly done in two-spark magneto construction.

Generally speaking, the requirements for the fuelizer ignition are similar to those for regular ignition. It is of advantage to have not less than two fuelizer sparks per revolution of the engine to assist in starting. Once the flame is established it will continue without the aid of a spark until such time as the throttle is suddenly opened. However, in practice it does not seem worth while to cut off the spark while the engine is running, although it is obvious that a simple thermostatic control could be worked out for this purpose. The spark-plug is of conventional construction except for the electrode, and this can be constructed in any manner desired without the restrictions imposed by preignition on regulation spark-plug design.

The Fuelizer vs. Hot-Spots

The question may arise as to the comparative merits of the hot-spot and the fuelizer. By hot-spot I mean any of the exhaust-heated manifold-designs in which the heat is more or less localized. I believe the best answer is that the fuelizer covers a wider range of actual service, but that the fuelizer in conjunction with a judicious use of additional heat from either the exhaust or a suitable water-jacket offers the best solution. The average exhaust-heated manifold warms up quickly if the throttle is opened when starting off; that is, if the engine is raced or if the car is run in low gear for a short distance. The fuelizer, on the other hand, operates to the best advantage when the engine is idling or operating under a reduced load. Under ordinary driving conditions the rate of mixture-temperature increase will be very much more rapid with the fuelizer. In exceptional cases, such as starting off cold at the base of a long hill, the exhaust-heated job may have the advantage, since this wide-open-throttle condition automatically cuts down the action of the fuelizer. A combination of these two systems covers every conceivable driving condition. Of course, as pointed out elsewhere, the application of the exhaust heat must be carried out carefully so as not to reduce the volumetric efficiency of the engine under wide-open throttle. In actual practice a suitably designed water-jacketed manifold gives excellent results in conjunction with a fuelizer, and this is of particular advantage in engine designs in which the intake manifold is on the side opposite from the exhaust manifold. Another point in favor of the fuelizer is that its design requires the least amount of metal exposed to a high temperature. When driving requirements change suddenly from light load to full load or vice versa, a suitable mixture temperature is arrived at very much more quickly with the fuelizer than with any exhaust-heated system. With this latter construction there is necessarily a greater mass of metal to cool off or heat up than with the fuelizer, and the time required to arrive at the desired temperature is necessarily prolonged.

The all-important advantage of the fuelizer over any exhaust-heated system is that it supplies the heat in exactly the amount needed to meet average driving condition. If an exhaust-heated manifold is made to give the mixture anything like the heat demanded for good idling and slow-speed work in cold weather, it will heat the charge unduly on a stiff pull on a hot day. This will result in a decreased power output of the engine and also an increase in heat loss to the jacket water which in turn requires great heat-dissipating ability on the part of the radiator.

What the fuelizer accomplishes under various conditions of operation is summarized as follows:

(1) In starting, it generally comes into operation even before the engine starts firing; this is especially noticeable in severely cold weather. The fuelizer is therefore of real service in insuring a prompt start
(2) For warming up, if the engine is allowed to idle for a few moments the fuelizer heats the manifold very quickly. Even in severe weather, when driving away immediately after starting up, the engine will fire regularly within a very short distance
(3) For hard pulling, dynamometer tests show absolutely no difference in power when running wide-open with the fuelizer connected or disconnected. It is obvious that, since no heat is supplied by the fuelizer under these conditions, there can be no loss in volumetric efficiency

I have endeavored to show that the fuelizer furnishes the proper amount of heat to the intake manifold under all conditions of running. This is accomplished in a very simple manner, particularly in some of the later designs, demanding practically no added complication to the engine except an extra source of ignition current which can be synchronized with the regular ignition current so as to form, if desired, a reserve system of engine ignition for emergency.

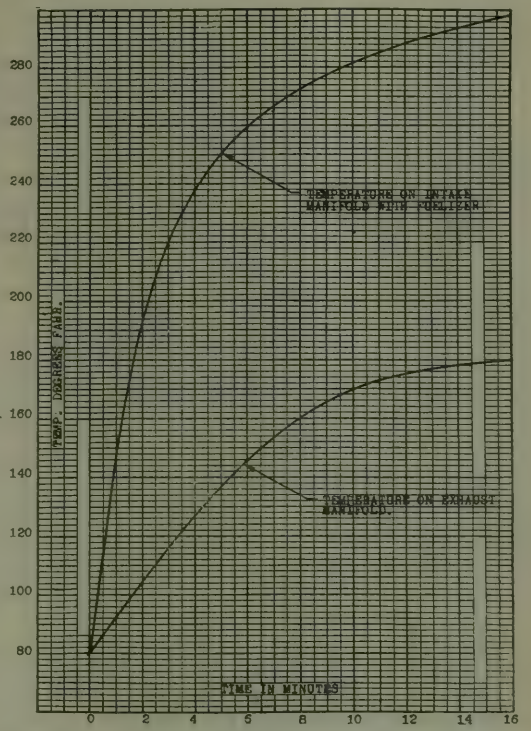


FIG. 3—CURVES SHOWING THE INCREASE IN TEMPERATURE ON THE OUTSIDE OF AN INTAKE MANIFOLD EQUIPPED WITH THE FUELIZER OVER THAT ON THE OUTSIDE OF THE EXHAUST MANIFOLD

THE DETROIT DISCUSSION

U. G. THOMAS:—How much gasoline does this fuelizer save?

L. M. WOOLSON:—That depends upon the driver. Recent tests show that if the fuelizer is operated to the best advantage and the mixture is made suitably lean, a substantial increase in gasoline mileage should be attained. It is difficult to persuade drivers to pay any attention to carbureter adjustment, assuming that there is some kind of dash adjustment. The average driver will pull out the choke to start and probably leave it in that position unless something happens to call his attention to it. In certain cars weighing about 3400 lb. we have consistently obtained 21 miles per gal. of gasoline with the fuelizer. We might obtain just as good or better mileage without the fuelizer in warm weather, the figure I have given refers to average driving mostly in winter. The advantage of the fuelizer is that it enables the engine to run with the leanest possible mixture. If the driver does not take advantage of this, it is of course of no avail. I hope we shall have carbureters that require no attention from the driver, these being controlled thermostatically or automatically in some other way. With such carbureters we could get increased mileages. On a certain car equipped with the fuelizer, the test results were 15.6 miles per gal. when running without the fuelizer, and 15.3 miles per gal. when running with it. The carbureter adjustment was the same in both cases. When running with a fuelizer, a much leaner mixture can be used; it is difficult to state off-hand how much gasoline that would save. I believe that if the mixture were made lean as soon as the fuelizer began its action, at least 15 per cent of the gasoline could be saved.

H. S. BENJAMIN:—Fig. 3 shows a rise in temperature of the intake manifold and the exhaust, and that the intake had a more rapid rise in temperature than the exhaust. If the exhaust manifold could be made of aluminum, what would be the comparison in the rise in temperatures?

MR. WOOLSON:—It would be far more favorable, but the ultimate temperature for idling would be very much greater in any case. We have measured temperatures on the fuelizer jacket walls of 800 deg. fahr. after a few minutes of idling; for instance, at the spreader of the V-type installation. The exhaust pipe never reaches any such temperature except when running with fairly wide-open throttle.

MR. BENJAMIN:—What is the temperature inside of the intake manifold during idling?

MR. WOOLSON:—It will vary. With a water-jacket it probably will never go much beyond 220 deg. fahr. because the heat conductivity of the water prevents further temperature rise. In the single-six installation the temperature will go very much higher under prolonged idling because the apparatus is bolted directly to the exhaust pipe and the intake passages are formed partly integrally; probably 330 deg. fahr. would be reached in time.

MR. BENJAMIN:—Do you not find that the heaviest

portions of some motor fuels do not vaporize uniformly at 450 deg. fahr.?

MR. WOOLSON:—We should not confuse the end-points of fuels with the temperatures required for effecting complete vaporization in a 15 to 1 mixture. Under sub-atmospheric conditions as obtained in a manifold, nothing like a 450-deg.-fahr. temperature is needed to get a dry mixture.

MR. BENJAMIN:—That is true. I had crankcase dilution in mind. A certain part of the fuel will get past the piston-rings and cause dilution. If the temperature in the manifold is about 280 deg. fahr. and the end-point of the fuel is 450 deg. fahr., there will be a certain amount of crankcase dilution.

MR. WOOLSON:—That would occur only if the fuel were in a saturated atmosphere.

PROF. O. C. BERRY:—Tests at Purdue University show that Mr. Woolson's point is correct. We use a piece of metal about 3 in. wide, 10 in. long and ¾ in. thick, with a slight depression in the top. Fuel is syphoned over into that depression. There is a heating element under the metal and holes are drilled alongside the depression, so that the temperature of the metal to which the gasoline or fuel is exposed can be determined. The results reported are the number of minutes required to vaporize 0.01 lb. of fuel from 1 sq. in. of heated surface. At 300 deg. fahr., about 7 min. is required to vaporize completely 0.01 lb. of Red Crown power gasoline on 1 sq. in. of heated surface and this grade of gasoline has an end-point of 450 deg. fahr. The correct mixture, as Mr. Woolson stated, has just enough gasoline to use up all the oxygen at 15 lb. of air for 1 lb. of gasoline. With a value of three for the gasoline vapor, we have 45 volumes of air to 1 volume of gasoline vapor; so, the partial pressure on gasoline is only 1/45 of atmospheric pressure. Although the temperature of this room is less than 212 deg. fahr., the boiling temperature of water, the water vapor in the room would create a pressure of something like ½ in. of mercury; that is, it is possible to have the vapor present in the atmosphere at a lower temperature than corresponds with the boiling point of the liquid. We had a clean dried-off surface at a temperature considerably less than that of the end-point of the fuel for that reason.

T. J. LITLE, JR.:—When using a rather lean mixture, did not the flame retreat into the interstices of the gauze at the upper part of the fuelizer and burn it? We experienced that trouble in the development of Welsbach-light burners, particularly with pressures such as occur in burning gasoline, kerosene, distillates, alcohol and the like. What is the extent of dilution incidental to the introduction of that much burned charge directly into the intake manifold?

MR. WOOLSON:—We originally used a 40-mesh screen. A lean mixture would burn a hole, frequently within 400 to 500 hr. But with the mesh we are now using, the heat conductivity of the aluminum body of the burner is sufficiently great to prevent any such action, no matter how lean the mixture is. We have run these for 2000 hr. and none of the screen was consumed. Regarding the effect of the dilution caused by the burned gases, there is a strange phenomenon that many people do not recognize. There is absolutely no effect that is noticeable to the driver. There is about a 10-per cent dilution at very slow speed, but the engine can be idled at a slower speed with the fuelizer than without it. In the Van Blerck installation, it is almost impossible to stall the engine. As a matter of fact, at ½ m.p.h. there is no noticeable effect as regards dilution; the idling is not affected. The only evidence of the presence of the dilution would appear upon disconnecting the fuelizer and letting the mixture that was burning in the fuelizer join the main mixture. In that case the engine would speed up slightly, because it would be getting slightly more mixture than before.

MR. LITLE:—My understanding is that the charge from the burner enters the intake manifold through small orifices. Do small projections of flame enter the screen and cause back-firing?

MR. WOOLSON:—We feared much trouble from this but have had none. The orifices must be far enough away from the burner body and the gases must be made to take a circuitous path if necessary. On an installation like that on the V-type engine, we use 3/16 in. diameter orifices. We have never experienced back-firing, but if the openings were increased to ¼-in. diameter there would be occasional back-firing.

PROF. BERRY:—It seems that in starting an engine in cold weather with the present grade of gasoline, if the temperature is too low, not enough gasoline is vaporized to support combustion and it is almost impossible to get ignition in the cylinder. Is the temperature below which we cannot go very much lower with the fuelizer than without it?

MR. WOOLSON:—The lowest temperature at which I have experimented with this device is about 10 deg. below zero fahr. We obtained very prompt ignition in the fuelizer burner body. We found we had ample heat in the spark there; it is only a matter of obtaining enough heat to start.

J. H. HUNT:—There is no such thing as a critical temperature, but the problem becomes progressively difficult. I think it is not caused entirely by the condition of the gasoline; I think the trouble is in getting the fuel to the place where we want it. The cranking speed is reduced greatly. Is there any specific figure for the amount of fuel that should be consumed in the burner, as compared with the amount of fuel that the engine is using when idling? Is there a ratio that could be applied, in going from one design of engine to another?

MR. WOOLSON:—That can be computed mathematically from the specific and latent heats. I believe a desirable increase of mixture temperature is something like 100 deg. fahr. To raise the temperature of the air and that of the fuel 100 deg., and completely vaporize the latter, something like 2 per cent of the British thermal units of the fuel dealt with must be consumed in the burner. The efficiency of the proceeding is fairly high. It is a kind of self-contained boiler proposition. It operates at something like 90 per cent fuel efficiency; so, it is simply a matter of what condition it is desired to meet. In arriving at the various calibrations we used common sense, not trying to go to extremes. We did not endeavor to melt the manifold, although that can be done. On an engine of about 400 cu. in. displacement, certainly not more than ½ pint per hr. should be burned at any time.

MR. HUNT:—What I referred to is more a matter of experiment than mathematics, because it is very certain that we want to use more than 2 per cent of the fuel that the engine requires when idling. We are not satisfied with simply a 100-deg.-fahr. rise to get a quick result.

MR. WOOLSON:—That is all a matter of the standard set. A 100-deg.-fahr. rise is considerable. It might not do for extreme conditions, but when we build apparatus like this, we try to meet average conditions. In connection with this fuelizer we try to make it as simple as possible; no matter how simple it is there is enough

cause for trouble. If enough heat were used to serve at 30 deg. below zero fahr., certainly some control would be needed to shut it off in summer, which would involve complication. By adopting a middle course, giving sufficient heat for the average result, we satisfy everybody, I believe, and avoid creating too high a temperature in summer. The device permits, however, the use of as much gasoline as one cares to burn. I have never found any limitations.

MR. LITLE:—Is not the greatest value of this fuelizer the heating of the manifold quickly? That is its greatest function, I should say. With a cold engine in winter one gets under way very quickly.

MR. WOOLSON:—Yes.

MR. LITLE:—Instead of burning ½ pint per hr., why not burn 1 qt. per hr., and then cut it off? Would it not be desirable to get under way more quickly?

MR. WOOLSON:—That would mean some sort of manual control. We wanted to avoid that. The average car is used for fairly short hauls in winter. The opportunity for cutting the fuel supply off would probably not present itself very often on a cold winter day. It would not be desirable to cut it off for 2½ or 3 miles. I question whether it would be worth while to make provision for the occasional driver. The device is actuated very easily by opening the ignition circuit, although the throttle has to be stepped on to extinguish the flame. Opening the ignition circuit would form a certain and practical way of controlling the action.

MR. BENJAMIN:—Is not the apparatus arranged to shut off at a certain intake temperature?

MR. WOOLSON:—It does not respond to temperature influences, but only to depression influences.

MR. BENJAMIN:—But as the throttle is opened the temperatures increase and the fuelizer shuts off.

MR. WOOLSON:—That is a fortunate incident. As the throttle is opened, no more heat is needed and, as the compression pressure increases and the amount of suction decreases, less mixture is pulled through the fuelizer and less is burned. Consequently, the heat decreases; but the response is to manifold depression only, and not to any other influence.

A MEMBER:—Fig. 4 shows that there are two sources of heat. The incoming gas receives heat from the exhaust jacket on one side of the fuelizer; the other source is the exhaust gases from the fuelizer that enter the manifold itself. Which source is considered the more beneficial?

MR. WOOLSON:—The benefit from one source equals that from the other. When starting cold the direct contact of the heated gases of the mixture undoubtedly helps for the first few seconds. On the other hand, when accelerating, it is very desirable for best results to have very high mixture temperatures. The heat that is stored in the metal comprising the fuelizer body is then relied upon. At low mixture-velocities the gasoline tends to hug the walls, deposit on them and creep up slowly. By having the walls hot, that effect is prevented.

A MEMBER:—What is the temperature of the gases that come in through the orifices in the fuelizer body itself?

MR. WOOLSON:—I cannot give accurate information regarding that. The temperature in the burner body is about 1000 deg. fahr. and where the burned gases in entering join the main gases they may have dropped 200 to 300 deg. fahr. during their passage. That is a fairly accurate statement. We have never put on thermocouples, because we thought that this was not necessary.

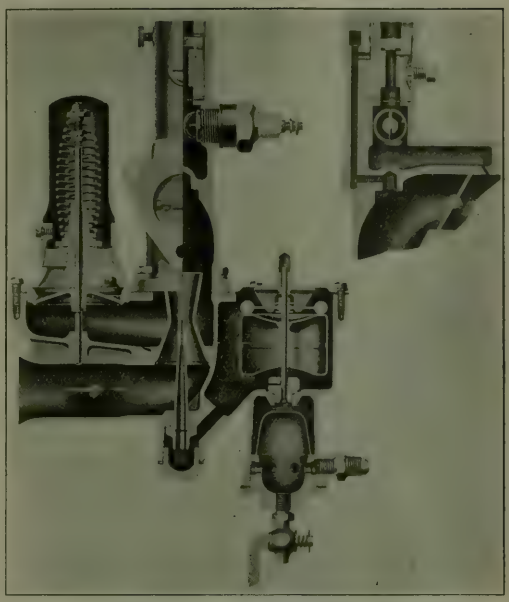


FIG. 4—AN APPLICATION OF THE LATEST TYPE OF FUELIZER TO A SIX-CYLINDER PASSENGER CAR

MR. HUNT:—The temperature of those gases is well over 2000 deg. fahr.

MR. WOOLSON:—When using aluminum bodies? How is that?

MR. HUNT:—The gases are cooled by the mixture on one side, or the device would not be possible. I refer to the flame immediately below the plug. The theoretical temperature, assuming that the specific heat of the air remains constant, is well up to 3000 deg. fahr.; we know it is above 2000 deg. fahr. until after it has been chilled, for we have actually measured the temperature of the flame.

MR. WOOLSON:—As a rule we use a cooler mixture that is somewhat too rich. We do that to get quick starting. A perfect flame would be colorless or very light blue and extremely hot. The flame we generally use is somewhat greenish in color. It probably contains a considerable amount of carbon monoxide. When running with a very lean mixture the heated electrode becomes red-hot, but not when running in the usual way.

MR. HUNT:—The pipe on your demonstration outfit is bright red. The temperature of the plug does not show the temperature of the flame.

MR. WOOLSON:—Not altogether. The point of maximum heat is determined by the richness of the mixture. A lean mixture will tend to burn up near the top of the flame. The rich mixture will tend to burn further down.

PROF. BERRY:—The statement has been made that the fuelizer is not so necessary for wide-open-throttle running as for starting up. As I understand it, the assumption is that under wide-open-throttle conditions there is better distribution through the manifold. I observed an engine under test conditions that did not seem to confirm this. It idled well and under throttled conditions at almost any speed seemed to give very good performance. But at high speed and wide-open throttle, it continued

to miss; we could not find any carbureter adjustment that would cause every cylinder to fire regularly. That was puzzling to us, because we were not expecting poor distribution under conditions of that kind. Finally, we substituted a good manifold from another engine and the trouble was eliminated. I am satisfied that the missing under the high-speed conditions of wide-open throttle was due to very poor mixture distribution in a cold manifold, even under those high-velocity conditions. Has Mr. Woolson made any experiments showing that at high speed there is better distribution of the liquid than at low speed, or whether the better engine performance is due to the fact that with high compression there can be a very much more poorly mixed charge?

MR. WOOLSON:—I qualified my statement that heat is not needed under wide-open throttle conditions, by stating that this applies only with a suitable manifold design. It is much easier to design a manifold that will give reasonably good distribution under wide-open throttle conditions than to design one that will give perfect distribution under idling conditions. Some engines have been built with the manifold so unsuitable that it would not distribute properly. Some airplane engines will generate more power under partial throttle, due to the stirring effect on the mixture. I think that problem can be attacked very much better by designing another manifold than by stifling the engine by heating up the charge.

PROF. BERRY:—Even with the best manifold, something is lost by cutting off heat at the wide-open throttle conditions.

MR. WOOLSON:—If that were the case, it would surely appear in the economy runs made at various temperatures. We ran a great many, with temperatures ranging from 90 to 212 deg. fahr.

PROF. BERRY:—Was that while using aviation gasoline?

MR. WOOLSON:—Yes, but aviation gasoline at 90 deg. fahr. is not very tractable; the fuel efficiency in pounds per horsepower-hour shows as nearly a flat line under those conditions. If the distribution were assisted to any material degree by the heating, it would be reflected in better fuel economy, would it not?

PROF. BERRY:—I believe it would be.

MR. WOOLSON:—Another way of looking at the problem of supplying heat at wide-open throttle is to consider what is done when a certain size of engine is to be designed, such as one of 200 cu. in. That size is selected because it is thought to be the smallest that will develop 50 hp., but the only way 50 hp. can be obtained from that size of engine is by keeping the mixture fairly cool. If the mixture is kept heated, the size of the engine must be increased; so I see no point in adding heat. The kerosene engine is a different proposition.

CHAIRMAN EARL G. GUNN:—Everyone who has had anything to do with engine design has certainly experimented with the heating of intake-manifolds in some manner or other. What is the effect of the fuelizer on a smoky exhaust?

MR. WOOLSON:—On a cold day an engine not equipped with a fuelizer will emit considerable kerosene smoke if opened up after prolonged idling. The same engine equipped with a fuelizer can be idled indefinitely and will open up clean. Much of our experimenting was done in the summer. We built a box around the manifold and filled it with cracked ice and calcium chloride. It produced fairly good results. Mr. Hunt can drive a car into the laboratory refrigerator room for experimental purposes, and that is the ideal way.

MR. LITLE:—After the engine has been in the refrigerator room, say for 24 hr. at 10 deg. below zero fahr., within how many seconds will the engine start?

MR. WOOLSON:—We made a test at about 5 deg. above zero, which was as low as we could get at the time. That particular engine started within 8 sec. The fuelizer started almost instantly. The engine was able to run idling in the refrigerator room within 20 sec. with the summer setting on the air-valve.

MILTON TIBBETTS:—It appears to have been taken for granted that everyone knows what results have been given with the fuelizer as regards crankcase dilution and spark-plug fouling. What are the actual results along that line?

MR. WOOLSON:—I have never seen or heard of an engine on which a fuelizer was operating that ever fouled a spark-plug. That covers an experience of 18 months with several thousand cars. I believe that a spark-plug could not be fouled under ordinary driving conditions on a car equipped with a fuelizer; the porcelain might break, the electrodes might burn off, or something else might happen, but the spark-plug will never foul in the accepted sense of the word. As to what is achieved in regard to crankcase dilution, with the fuelizer in operation we do not maintain the viscosity of the oil at the original figure, because that is not necessary. But we keep the crankcase oil from building up in winter. The engine uses its regular amount of oil, and its viscosity is reduced somewhat in cold weather, but that does not matter. Not much dilution is required to reduce the viscosity slightly. One of the most needed accessories at present is some sort of simple viscosimeter. We tell the owner to test the oil, but he can do this only in a very crude way. Some efficient way of testing oil is required because much oil is wasted. Garages should be equipped to recover good oil from oil that is now thrown away. Many makers tell people to throw away the oil every 500 miles. That represents a considerable waste of the petroleum resources of the country; it must amount to several millions of gallons annually. Something ought to be done about it.

G. E. GODDARD:—Have you made any tests to show what percentage of gasoline the oil contains when running with and without the fuelizer?

MR. WOOLSON:—We generally make these tests with weighing apparatus. We made many oil-consumption tests with the fuelizer and without it. This can be done on the dynamometer very well. The oil supply increases at a definite rate when running without a fuelizer, due to dilution. If the fuelizer is kept in action and a dry or nearly dry condition maintained, the difference is something like 4 oz. per hr. under idling conditions, with the water temperature at about 100 deg. fahr. While crankcase dilution is not entirely eliminated with the fuelizer, it is eliminated to such an extent that it is no longer a problem.

A MEMBER:—Will the manufacturer build a fuelizer adaptable to almost any car having a manifold such as that on the Ford car, and that will tend to eliminate all trouble?

MR. WOOLSON:—We have tried the fuelizer on many different makes of car. There was not a case in which we did not get better results.

MR. TIBBETTS:—Mr. Woolson and I have worked together on that and the Packard company has tried to cooperate with other manufacturers in this matter of adapting the fuelizer to various cars, particularly the old ones. So far we have not been able to do that. I do

not know whether we ever will or not. It is a large problem.

THE CLEVELAND DISCUSSION

MR. WOOLSON:—Fig. 5 shows a cross-section of the fuelizer, which I will describe briefly. It has a conventional-type carbureter. The suction plugs are located above the throttle and have 3/16-in. holes. When the engine is running slowly there is a high suction that draws in a mixture of gasoline and air through the burner, where it is ignited. Heat is communicated to a portion of the manifold and the burned gases go down through the side walls. We thought we would encounter preignition. As a matter of fact, we observed flame coming out at these plugs and we had no difficulty with it at all. It was easy to cool the mixture and so prevent premature firing. The small carbureter is built in the simplest way. It is a difficult problem to carburet say from 0.1 to 0.3 pints of gasoline per hr. The annular spray is 1/64 in. The mixture issues from the small carbureter through an elbow which has a peculiar construction. It then goes through a screen and, passing a plug, is ignited. The ignition is continuous between closed and half-open throttle. The manifold is water-jacketed. That is in connection with the desirability of having some heat on wide-open throttle. As regards heat during acceleration, we get that by having plenty of metal directly under the flame. That provides the heat necessary while accelerating, and it cools off rapidly under a hard pull.

When starting up cold the air-valve spring is highly compressed and the choke which controls the air is almost entirely closed. We found that to start the fuelizer burning promptly a somewhat richer mixture was required until the burner heated up. That sounds simple enough but it bothered us for a long time. To make the mixture rich, we take the primary air of the small carbureter from the secondary air passage of the main carbureter. When we shut off the air from this passage, we also cut off the supply to the auxiliary carbureter. It then gives a richer mixture.

I have made many tests at low temperatures, such as 10 deg. below zero fahr. The fuelizer generally starts burning an appreciable time before the engine commences to run. In fact, it is easily conceivable that it is the heat supplied by the fuelizer that assists in the starting of the engine. In Fig. 3 it will be noted that the burned gas joins the main mixture at two places. Getting equal distribution of the burned gas presents a problem, but it is not a difficult one. We thought, with others, that there would be no trouble when idling, but the engine equipped with a fuelizer will idle as well, if not better, than one not so equipped. The burned gas is practically inert; the condition is like admitting free air to the mixture.

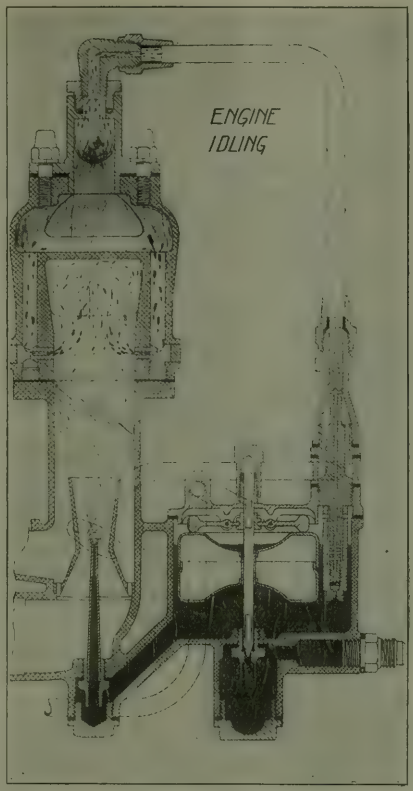


FIG. 5—CROSS-SECTION OF THE FUELIZER AS USED ON A TWIN-SIX PASSENGER CAR

K. B. BRITTON:—Is there complete combustion?

MR. WOOLSON:—That depends largely upon the quality of the mixture. We have made no exhaust-gas analysis. We can tell by the color of the flame in the burner body what kind of a mixture there is. We know that combustion is aided by having high compression but in the case of the fuelizer we are carrying on combustion in a partial vacuum. As soon as the tricks of burner-body design are known, it is easy to insure combustion under all conditions. In a wide-open throttle condition, the volume of mixture drawn through the burner body is very slight. No appreciable heat is given off under wide-

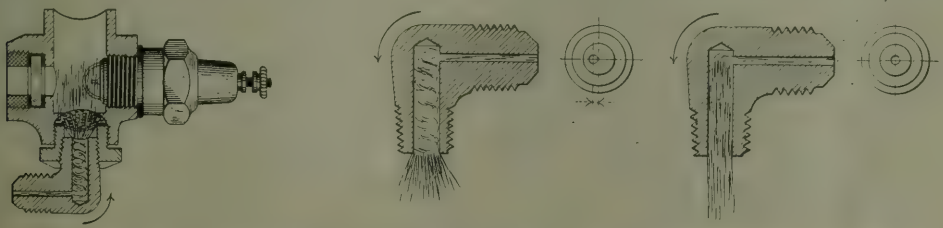


FIG. 6—SKELETON VIEW OF THE BURNER BODY AT THE LEFT, THE CORRECT FORM OF ATOMIZING ELBOW IN THE CENTER AND THE INCORRECT FORM OF ATOMIZING ELBOW AT THE RIGHT

open throttle, because the amount of gas in the burner is limited.

The drawing at the left of Fig. 6 shows what conditions must be obtained to get combustion. It is important that the mixture be atomized and distributed evenly in the burner body; it is not effective to distribute it unless it is atomized. Atomizers for oil for fuel purposes are complicated in form; so we began designing atomizers. We hit upon the design shown rather accidentally, and we have not been able to make an atomizer work any better. A screen with a peculiarly shaped orifice is located at the top of the burner body. Certain shapes of orifice give the best results. The spark-plug has a loop terminal and a gap of ⅛ to 3/16 in. The theory is that any time an inquisitive mechanic takes out a plug with a wide gap, he will narrow it down and cause trouble. It is important to locate the spark in the right place. The best working condition is shown in Fig. 6. The glass inspection window has not given any trouble and offers an interesting opportunity to inspect the operation.

Two conditions of the simplified atomizer are shown at the center and right of Fig. 6. The hole in the central drawing is slightly off center. We test these holes by allowing a stream of water to pass through them. If they are not off center we get the effect shown at the right. There is a great difference between the operation of the two sprays. The screen is located at the proper distance below to straighten the spray out in the burner body. Incidentally, the small hole in the atomizing elbow prevents popping-back. We were bothered at first by popping-back; when combustion started, there would be a flare-back that made the pipe hot. That was solved simply. The velocity through the elbow was increased. That eliminates any popping-back tendencies. The hole is 3/32 in. in diameter on the Twin-Six engine.

Fig. 4 on page 245 shows the later development of the fuelizer. The passage which communicates with the elbow is located in the correct place to pick off the right mixture. In our earliest experiments we tried to do that, but it is surprisingly difficult to pick off a uniform mixture from a carbureter of this type; a spotty mixture is obtained. But by experimenting we determined the design shown in Fig. 4, which gives uniform results. This design enables us to set a carbureter by the color of the flame in the fuelizer. The fuelizer will burn all kinds of mixture except the very richest. At the lean end, the fuelizer will burn a leaner mixture than the engine will run on. Through the glass shown over the burner body we are able to see the color of the flame. It is surprising how the color changes with the mixture. A perfect mixture is represented by a sky-blue flame; the electrode gets bright red. A rich mixture will give an emerald green color. In a very rich mixture, the liquid gas can be seen. This carbureter is somewhat unconventional in design in that the throttle is distant from the jet. Since we made this design we have been able to simplify the picking-off point and adapt it to a conventional carbureter of any make.

A MEMBER:—What mixture works best for idling?

MR. WOOLSON:—There is no way of determining that. The fuelizer can be adjusted to use mixtures varying from the richest to the leanest; there is no perceptible difference. The volume of gas is such a small percentage of the total that it does not affect the whole.

A MEMBER:—What percentage passes through the fuelizer when the engine is idling?

MR. WOOLSON:—At the most about 0.4 pint per hr.; about 5 per cent.

A MEMBER:—Is that for wide-open or closed throttle?

MR. WOOLSON:—At wide-open throttle very little mixture goes through the fuelizer.

A MEMBER:—What is the pressure drop at wide-open throttle?

MR. WOOLSON:—It may be from 1½ to 2 in. of mercury. I am not prepared to state accurately. On the other hand, there are many constrictions between the vaporizer and the burner body. There is no perceptible amount of flame with less than 6 in. of mercury depression in the burner body.

H. B. MASSEY:—What experience have you had at 10 deg. below zero fahr.? Will the fuelizer heat before the engine starts firing? Can its heating be depended upon?

MR. WOOLSON:—If the choke is pulled out it will invariably light. We paid particular attention to that.

MR. MASSEY:—At 10 deg. below zero, about how long does it take to crank the engine?

MR. WOOLSON:—About 3 sec.

A MEMBER:—How long will it burn with one spark?

MR. WOOLSON:—It can run without any spark. No spark is needed after starting, but a spark is necessary after sudden acceleration. In cold weather it is desirable to get all the heat obtainable.

A MEMBER:—What is the difference in mileage with and without the fuelizer, under the same conditions?

MR. WOOLSON:—I have made tests under flat running conditions. I obtained 15.5 miles per gal. without and 15.2 miles per gal. with the fuelizer; the difference is very slight. Under severe conditions, such as a series of accelerations, the improvement in acceleration due to the fuelizer will give better mileage with it than without.

A MEMBER:—If the acceleration were the same, would better mileage be obtained with the fuelizer than without it?

MR. WOOLSON:—Yes, acceleration is improved about 20 per cent by using the fuelizer and the pedal can be held down for a shorter length of time.

A MEMBER:—What percentage of the fuel entering the manifold is vaporized before reaching the cylinder?

MR. WOOLSON:—All I can say is that a sufficient portion is vaporized to give us what we need; it is of no advantage to go further, but we could increase the amount of heat.

A MEMBER:—What is the difference in carbonizing, with and without the fuelizer?

MR. WOOLSON:—Our claim for the results regarding carbonizing is based on the knowledge that we experience no spark-plug trouble. If the spark-plugs do not foul, it is reasonable to suppose that the carbon deposit is not formed. Detonation has more to do with the causing of carbon deposits than any other factor. Mr. Kettering, Mr. Horning and others are working on this problem. When we eliminate detonation, we will get rid of a main cause of carbon deposit. A deposit of the same depth of carbon with present-day fuels causes twice the spark knock that high-test fuels cause and this is responsible for the general complaint of carbonizing. This device takes care of carbon resulting from the burning of kerosene. There will be naturally more carbon in an engine using a wet mixture than in one in which the mixture is dry. We found we could run at least 1000 hr. and show no carbon on the fuelizer screen when the mixture was correct. If the mixture is rich, a carbon deposit occurs within 500 hr. and necessitates cleaning the screen. With a correct mixture it will burn clean indefinitely. That is

(*Concluded on page* 254)

Addresses at the Annual Dinner

THE Annual Meeting terminated on the evening of Jan. 13 with the highly successful Society dinner at the Hotel Astor, over 1100 members and guests being present. After appropriate remarks, President J. G. Vincent introduced Past-President C. F. Kettering as toastmaster for the evening. The other speakers were David Beecroft, then president-elect of the Society; R. E. M. Cowie, vice-president of the American Railway Express Co., whose subject was the Coordination of Transportation Media; and George E. Roberts, vice-president of the National City Bank, New York City, who spoke on the Crux of the Present Economic Situation.

ADDRESS OF PRESIDENT-ELECT BEECROFT

I WISH to thank the fellow membership for the honor conferred upon me. It is a great privilege to have the opportunity of heading an organization of over 5000 men and to be president of an engineering society that is unique in that it represents a circle of industries. This circle is composed of eight distinct but closely related industries, all centered about the use of the internal-combustion engine. The automotive engineer probably requires the services of the editor more than other engineers because the piece of apparatus in which the internal-combustion engine is installed has gone into the hands of the average citizen of all the countries in the world and it is necessary, if we can get the information from the engineer, to carry the message to the users of this apparatus rationally as to how it should be used.

Editors think that this apparatus is yet far from being in a perfected state. We are glad to have the laymen agree with us in that. The motor car, which is not the oldest of this circle but is the largest, still has many problems ahead. We give all credit to those engineers of Europe who, in 1885, began bringing together the fundamentals, and we have wisely builded upon their early work. There is one great credit that goes to the Society of Automotive Engineers; namely, that it had the good judgment to take and translate into the requirements of this country those fundamentals that were so well worked out in Europe. It was very fortunate that our manufacturing centers were located in the region of the Great Lakes, bordering on one of the greatest agricultural areas in the world, an area that has already given evidence of being one of the great consuming areas of automotive apparatus. What is happening in this agricultural area is happening in all similar areas in the world. We could scarcely do anything else but develop automotive apparatus and translate it into what we now have. It was the voice of those thousands of square miles of country calling for apparatus, the voices of those 7,000,000 farmers demanding improved transportation and the voice of great areas with sparse population, requiring some speeded-up method of transportation in order that the homogeneous character of this country should be maintained and that the urban population should not lead the rural too far, that induced automotive development. What has been a greater factor in bringing the rural population up to the level of the urban population than the internal-combustion engine in its various forms?

We developed this apparatus and the great production plans that have carried internal-combustion-engined apparatus to the four quarters of this country. In the earlier years of the war we found the nations of the world knocking at our doors for this apparatus and we immediately gave heed. Soon, this apparatus, so well fitted for our areas of poor roads, great distances and sparse population, found itself excellently fitted for use by the nations of the world. We unconsciously came by a great heritage in that we builded in the zone of requirements where conditions were crude, whereas Europe had been building under conditions that called for a different type of vehicle. We have this great field ahead. We have found our factory capacity greatly expanded because of the war. We must give attention to the remainder of the world. The motor vehicle is an international piece of mechanism in all its forms and our engineers must look beyond the confines of their own country. I can think of nothing that would be more useful today than that these engineers go into other countries and see the conditions under which their apparatus must operate, see face to face the peoples who are destined to handle it, and then have due regard for those conditions in the improvement of the apparatus.

What must be the ultimate object of the engineer in all this apparatus? In its design he must recognize the work, the people and the environment, always keeping in mind that he is best serving this country and all the countries of the world to which our apparatus must go, when he designs and makes the apparatus so that it is easiest to purchase, easiest to apply to the job, easiest to operate and easiest to maintain.

ADDRESS OF R. E. M. COWIE

IT was aptly said by the toastmaster, in speaking of the different means of express transportation, that everything from a wheelbarrow to an airplane is included in our service. The express business began some 75 years ago. It was not dignified at the start even by a wheelbarrow, because the single individual who originated the industry relied upon a gripsack. Within a very short time his business increased enormously and he had to invest in this wheelbarrow, but even that proved too small for his needs and led him to obtain certain space in a stagecoach. From that the business turned to other modes of transportation, the boat on the inland waterway, the steam railroad and steamboats, and has developed now to include every known means of conveyance. Until a few years ago, the express traffic in the cities was carried almost entirely by horses and wagons, in these days regarded as a slow and tedious means of transport. The American Railway Express Co. employs today upon the Island of Manhattan 650 motor and 550 horse-drawn vehicles.

There is a very distinct place for the motor vehicle, whether propelled by electricity or by gasoline. There is just as distinct a place for the horse-drawn vehicle. It is unfortunate that horse-drawn and motor vehicles must operate in the same string of traffic. I do not know how that can be remedied in the densely populated cities, but the problem must be solved.

Simplification of Product

The motor vehicle is a wonderful machine, but it is too complicated. It takes a high degree of intelligence and engineering skill to design a vehicle of so many different parts, coordinate those parts into one apparatus

and make it function successfully. Still greater ability is requisite to eliminate a number of those parts. The cost of upkeep of the ordinary motor vehicle makes the average man stagger. This is due in part to the present high cost of labor and material, but if there is any way to simplify the internal-combustion-engined vehicle, I advise that this be done. Forget about what competitors do. It seems to me sometimes that the sales department of the average automobile manufacturing company merely wants the engineering department to put on fancy appurtenances so that it can have some little points to talk about that competitors do not possess. Wipe all these off; eliminate from the chassis everything but the absolutely essential parts. The efficiency of the vehicle will thereby be increased, its cost of operation reduced, and a greater field for its sale opened. The motor vehicle may appear to a scientific man to be a very much simplified machine, but we cannot get scientific men to operate our motor vehicles. The simpler the machines are, the more efficient they are, the less liable to trouble and the more economical in operation and upkeep. I cannot imagine any line of study that can be more profitably followed by automotive engineers than the simplification of the product in which they are interested.

The value of the motor vehicle as a means of transportation cannot be overestimated. The things that it has accomplished are marvelous. When the United States decided to enter the recent war, money and motor vehicles were preeminently needed and these two things were immediately found and furnished in this country. The engine that automotive engineers designed and the motor vehicle that they constructed won the battle of the Marne, prevented the fall of Paris and changed the whole complexion of the war. It was possible for the United States Government to furnish, for itself and for the Allies, vehicles to motorize the artillery, the ambulance service, the food service, supply and ammunition trains and everything that must follow up or precede an army, because the automobile industry was upon a sound, going basis and foundation.

Fostering of Commercial Aviation

The United States Government should adopt a far-sighted, consistent and constructive policy with respect to commercial aviation. It is true that the Government has, through meager appropriations by Congress, been able to conduct certain mail routes which, considering all the circumstances, must be admitted to be signally successful. I can conceive of no good reason why the Government should not encourage and support commercial aviation in the same manner that it has encouraged and supported navigation on the seas. In the one instance the Government furnishes maps, charts, lighthouses, whistling buoys, life-saving apparatus and the like. Why should it not furnish landing fields, illuminated airdromes, wireless directional apparatus, licenses, proper legislation and all the things calculated to make commercial aviation successful? From an experience of many years in the transportation business, I believe that the people of this country would avail themselves very quickly of service by air, just as they availed themselves quickly of service by parcel post. The parcel post attracted and built up a business peculiar to itself. I predict that the airplane service, where it covers a sufficient distance to eliminate a certain amount of time, will be taken advantage of immediately by the commercial interests of this country. Commerce presistently demands the most approved and expeditious means of transportation. I hope that soon the United States Government, through its mail department, and the American Railway Express Co. will join traffic and use the same machines to encourage commercial aviation. These must be specially built machines for carrying the Government mails and the extra emergency shipments offered by the public for express transportation.

In my judgment, the possibilities of commercial aviation offer the members of the Society of Automotive Engineers as great a field of endeavor as any field they have entered.

REMARKS OF C. F. KETTERING

WE have not really awakened yet to a realization of what aviation is. If we talked about everything the way we do about aviation, we would still be riding around in ox-carts. I have said time and time again that we have a lot of people riding in automobiles who have ox-cart minds. The great trouble with aviation is that we do not appreciate what a tremendous thing it is. We do not appreciate the meaning of an increase in the speed of transportation of from three to five times what we have ever had before. The idea is too great for people to grasp. We certainly wish to thank Mr. Cowie for his stimulating message to this audience in favor of aviation. When an unbiased, unprejudiced individual talks that way, those are wise who pay some attention to what he says.

There are two kinds of aviation, military and civil. We have had two aviation clubs in this country, the American Flying Club and the Aero Club of America; but they have come together and made a good landing in that the two have now become the Aero Club of America. The club has a membership now of 2000, of whom 850 are pilots. We want to increase that membership so that members of the Aero Club of America will reside in every town, village and hamlet in this country. We want members to have a feeling that belonging to the Aero Club of America means something. It is a pioneering of the most wonderful thing that mankind has ever created for his own use. The automobile is wonderful and has fulfilled in a wonderful way the requirements of utility, but it must run on the ground. When flying in the air we can go straight and do not need any right-of-way. So let us support this Aero Club of America. Let us help to obtain these airports, lighthouses and other necessary equipment. We have airplanes and engines, but what would a great, massive railroad engine and its wonderful train be worth if we had no railroads to run them on? Today we have none of the essentials of aerial navigation; only by getting popular support will we ever obtain those essentials.

Most people when they go up in an airplane for the first time and the pilot gives them a "stunt" flight, come down and say that they would not accept $1,000,000 to do it again; on the other hand, if the pilot gives them the right sort of a flight, they come down and say that it was the most wonderful experience they ever had. Everyone ought to take a ride in an airplane. If an airplane passenger has any personal conceit, such an experience will remove it before he again reaches the ground. If one is general manager of some great factory, reaches an altitude of 5000 ft., looks back and sees a little bit of a factory about the size of a postage stamp, one is bound to realize that he is not so much, after all. Nothing else in the world will give one such a perspective of the relationship of individual activities to world activities as a flight in an airplane. I said, the first time I went up, that it looked to me very foolish to quarrel about

A PORTION OF THE GRAND BALLROOM OF THE HOTEL ASTOR, NEW YORK CITY, WHERE THE ANNUAL DINNER OF THE SOCIETY WAS HELD ON JAN. 13.

2 ft. on a line fence, one side or the other, and I still think that. So, we want the backing of everybody in the Aero Club of America. The aerial mail service is the great commercial laboratory for the flying machine, and yet I understand that Congress is in doubt about appropriating any money for it.

We have had two men speak about the necessity of studying automotive apparatus from the user's standpoint, and I think we all realize that this is a fundamental problem. Of course they are blaming all the faults on the engineers. No class of people realizes the faults of automotive apparatus any more than the engineers do, because engineers look over the trouble reports and others do not. Our whole economic situation has changed. We must build an entirely different type of apparatus in the future than we have in the past. We must recognize that the customer who pays for these automobiles has a right to ask for something, and that unless we design from the standpoint of the customer, we will get into trouble. If President-Elect Beecroft will focus his attention on that particular idea and print it and talk about it to the commercial side of the industry so that it will not overrule the engineers, that will help very much.

ADDRESS OF GEORGE E. ROBERTS

WE bankers have a consciousness that the automobile business has never felt under any particular obligations to the banking business for helping it to get started, and we are content to have it understood that a new business, as well as an individual prospective client, must make good before accommodations can be obtained from the banking business. The automobile business has made good. It has demonstrated that it is a utility, which is one of the things that was required of it. It is not always remembered that a banker is lending the funds that belong to others. He is a trustee for the funds in his possession, and he has no business to take any chances with them. It is not his business to promote new enterprises. He asked of the automobile business that the machine should demonstrate its durability; that it should demonstrate itself as a practical machine in the hands of the average man. It has demonstrated that. It has demonstrated that nobody who has ever owned an automobile will get along without one again, if he can avoid it, and that is good proof of success.

If anyone should know what is the matter with this world and the remedy for its troubles, it ought to be the engineer. He is not only the man to obviate its troubles but, in some degree, he is responsible for them. I mean by this that the primitive man did everything for himself and was independent, but gradually it was discovered that if a man devoted himself to one thing he acquired skill, and that if everybody devoted himself to one thing and all exchanged products with each other, there would be more of everything for everybody. So began the division of labor. Along with the division of labor came the engineer, who set about devising means to increase the productive power of the individual and to increase production, and along with the engineer came the development of capital. Capital, after all, is nothing but the machinery, tools and equipment that the engineer works with in production. The engineer, ever since, has been improving and developing the means of production, and always calling for more money. Thus it is that we have gotten this highly developed, intricate, highly organized state of industry that we have today.

One of our troubles is that the engineer has developed this industrial organization beyond the comprehension of the average man. So long as a man did everything for himself, he knew that the harder he worked, the more he would have. When he exchanged work with his neighbor, he had the whole transaction before his view; but when he works with thousands of other men for a great company, doing perhaps but one slight operation in the course of the production of an article, and the product is sold on the market, he has only a very small part of the process under his view. He loses his relationship to his fellow workers and to the consumers. He does not understand the process. He does not know very much about political economy. He does not know whether he is getting all he is entitled to or not, and he suspects that he is not. Moreover, this highly developed system of industry is wonderfully effective so long as it is working smoothly in perfect balance, with all its parts adjusted to each other, every branch of industry running to capacity and all branches exchanging products with each other; but it approaches the character of a great machine which, if any part is thrown out of order, is all brought to a standstill. That is the situation in which, to a very great degree, this country is at present and in which the world is at this time.

Industrial Depression

We are experiencing a period of industrial depression, and it is a world situation. We will not have any proper appreciation of the situation, its causes or the possible remedies, unless we understand from the beginning that it is a world situation. Wool has fallen, not only in the United States, but in Australia, Africa and South America. It affects coffee in Brazil, sugar in Cuba and Java, rice in India and silk in Japan. The people of all these countries are eager to sell their products, and to buy, and are unable to do either. Millions of people are out of employment and unable to buy the products of others because they cannot sell their own. This is not a general state of over-production. There never is a state of general over-production, but there often is, and there is now, a state of unbalanced production. The equilibrium throughout industry is the first requisite of a general state of prosperity.

We all understand that the unsound core of this whole situation is Europe. Europe was a great industrial community, gradually developed, accustomed to receive raw materials and food-stuffs from all over the world and to pay for them with its manufactured products. The war broke down this highly organized, slowly-developed, intricate, complicated system of industry and exchange, and it has not been reestablished since. This loss of the equilibrium in world trade has cost us our equilibrium in this country. It has reacted upon this country in the great fall in the prices of food-stuffs and raw materials. We have been accustomed to boast that our resources are so varied and so great that we can be practically self-contained and independent of the rest of the world. We could come nearer to being so that any other country. If we had organized and developed our industries with that purpose, we could be self-contained and independent to a very great extent; but our industries have not been developed with that thing in view. They have been developed as a part of the world industrial organization. Because of our marvelous natural resources we have found it to our advantage to develop those resources not only to supply our own wants, but with a view to supplying the needs of other peoples whose natural resources

are not so great as our own. We can work up into cotton cloth only about one-half of the cotton that is produced in this country; the same thing is true as to the consumption of food products and of raw materials of many kinds. Our people are and have been dependent for a part of their market upon foreign peoples. The inability of our foreign customers to buy the usual amounts and the falling off of that foreign market has disarranged our industry and thrown our industrial system out of balance. A state of general prosperity, either in international trade or in our domestic affairs, is impossible without an equilibrium in industry. There cannot be a free, full circulation of goods, a full employment of the people or the desired consumption of goods, unless the industries are in balance. All business, in the last analysis, is simply an exchange of products.

In the natural order of things, the population distributes itself in the various industries automatically in such a way as to keep them in balance, so that the products of each industry are absorbed by the other industries. Anything which suddenly disturbs that balance upsets the entire industrial system and prostrates industry throughout the country. That is exactly what has happened. Approximately one-half of the people of this country live either upon farms or in towns of less than 2500 people which are closely dependent upon farms. That end of our industrial system has been let down. Europe has let down the farmer and the farmer has let down our own industrial system. I need not tell you that a farmer whose income last year was $2,500, or $3,000, for example, and whose income from his present crop will not be over $1,200, or $1,500, cannot buy the same amount of factory products that he did last year. That is not a matter of opinon; it is a matter of arithmetic. That situation has to be understood and met. I do not wish to talk as a pessimist or as an optimist; I simply want to present the facts so that we can consider them as we talk about a speedy revival of industry. We may have our spurts of revival, but I believe there cannot be a general state of prosperity again unless the town industries and the great farming industry, with the people immediately dependent upon it, are brought back into a comparative state of balance.

Industrial Rehabilitation

I wish to present this thought, which is pertinent to the engineer. There cannot be a state of efficient production in a factory unless all departments are in balance with each other. I want to drive that point home. This situation may regain its balance through a rise of farm products, which has already taken place to some degree, but we must recognize that the price of farm products will continue to be dependent very largely upon conditions abroad and that it is beyond our control. The situation may improve through a general reduction of costs in the industries, so that the goods which the farmer and the general public buy come down to something like a normal relation with the other products which have already fallen in price. Either the one class of production must rise or the other classes must come down. We all know that it is comparatively easy to bring wages and prices up together, because everybody cooperates in the effort to raise prices, but when it comes to reducing prices many obstacles are in the way. The length of time required to regain prosperity depends upon the length of time it takes the business community to grasp the truth that industry and business must be brought back into balance.

No one likes to say much about reducing wages. I do not blame the wage earner for not wanting to accept lower wages but, in considering wages, we must consider all the rising wages and rising prices of the last 5 years. Then we must realize that all those things that went up together must come down together; at any rate, they must be brought together in some way before we shall have again a general balanced state of prosperity. The wage earner naturally says that he does not want to lose the gains which he made during the war. I do not want to see him lose them but, if the cost of living comes down, if flour and meats cost only one-half as much as they did before and if the farmer is feeding the city population at one-half the cost of a year ago, it is no sacrifice on the part of the town populations to take a reduction in their wages. It is not only no sacrifice; it is right. It is no more than what is just in bringing the situation back into balance. It is not a sacrifice because there is nothing else that can be done. It is a mere fiction to say that wages are maintained because wage rates are maintained. If one-half the wage earners are walking the street or working only three days in a week, their wages are reduced. Under such circumstances as exist now, they will be reduced, no matter what the agreement may be between employers and employes. All the employers of an industry and all the wage earners in that industry, together, do not have it in their power to fix the amount of wages that will be paid in that industry. The amount of wages that will be paid in any industry depends upon the amount of goods that can be sold, and the amount of goods that can be sold depends upon the ability of the public to buy.

One other way in which the situation can be met, that will appeal to the engineer, is by improvements in the methods of industry. Automotive engineers have led the world in that respect in recent years. They have shown the whole world how industry can be revolutionized by highly organized production. They have been teaching lessons to all the industries. They have done more than any other set of men to teach the lesson that the essential thing about wages is not the wage rate per week or per day, but the cost of labor per unit of product. That is the golden key to the solution of this entire industrial problem. The interests of wage earners, employers and consumers, can be reconciled by increasing production. We have the task of convincing the great body of people of this country that they are interested in large-scale economical production, and of convincing the wage earners of this country that they are interested not in restricting but in increasing production. In reducing the cost of all the necessities and the comforts of life, we must appeal to them. They must have a vision of the part they can play in the development of society. There is no limit to the improvements of that kind that can be made.

Money and Credit

There are those who think that the bankers are to blame for this reaction in industry, because they have been restricting credit or, as some have said, contracting credit. The best answer to the charge that they have been contracting credit is the record of bank loans in this country. The report of the Comptroller of the Currency shows that between June 30, 1919, and June 30, 1920, the bank loans of the United States increased approximately from $24,000,000,000 to $30,000,000,000, about 25 per cent. The bank loans of this country have increased twice as much since the armistice as they did during the war. There has been no increase in the physical production of the country in that time and no increase in the

amount of goods exchanged in the country. Therefore, why should there be such an increase in the amount of money or credit required to carry on the business of the country? Someone will say that wages and prices increased and that more credit was required to carry on business. Wages and prices did increase, but what made them increase? That raises a controversy as old among economists as the one in natural history as to which came first, the egg or the hen. Did the rise of prices cause the inflation of credit, or did the inflation of credit cause the rise in prices?

If there is anything that economists agree upon, it is that if the amount of the circulating medium, the supply of money in circulation or of credit which is in circulation as purchasing power, increases faster than the amount of goods to be exchanged, the value of the circulating medium will depreciate, and this means a rise of prices. The first impulse to the rise of prices came, no doubt, from the war. The war created an enormous demand for labor and for materials. The Government let contracts by the wholesale and the contractors bid against each other for labor and supplies. The ordinary demands of business in trade did not fall off because, with full employment for everybody, rising wages and the enormous disbursements of the Government, trade was better than ever. The banks were called upon, as a matter of patriotic duty, to lend money freely to support business and to people who would buy bonds. They did so on the theory that it had to be done to increase production. So long as there was any slack in the industries, these loans did increase production, but after every man is at work and every machine is running, that is about all that can be done. The point is reached where the most obvious way in which one employer can increase his output is by stealing labor from another employer. This is what was done. A procession of wage earners moved from one plant to another and had their wages raised at every move. When an organization is running to its capacity, if an attempt is made to drive it harder, all that is accomplished is to drive wages and prices up. That is what occurred and that is what brought out of the war this high level of wages and prices.

After the armistice there was a pause. Business men hesitated for a time to ascertain the trend of affairs. It developed that the private demands in industry would take the place of the war business. The soldiers were absorbed into the industries. In a short time the demand for goods, labor and materials was as great as it had been during the war. The war situation was repeated. Everybody had more business than he knew how to take care of, and there was the same pressure upon the banker for credit. In such a situation there is grave danger that the free granting of credit will simply finance a competitive struggle for labor and materials and drive the rising price movement still higher. Every merchant naturally wants to buy all the goods that he thinks he can sell. Every manufacturer wants to make all the goods that he thinks he can sell. But if the sum of all they think they can make and sell is greater than the capacity of the industries and in excess of the labor capacity of the country, and if every bank grants loans freely to its customers so that they can bid, nothing is done except to drive wages and prices still higher.

The fact is that people think credit can take the place of capital to a greater extent than is possible. Credit is purchasing power. Things can be bought with credit, but they cannot be made with credit. Labor and materials and machinery are needed to produce things. Credit is an intangible thing; it is faith and confidence. Capital is always something tangible; it is real estate or machinery or materials. I repeat that if credit is granted so freely that the supply in circulation increases faster than the capital actually in use, nothing is accomplished except to drive wages and prices upward. This is the reason that the banks of the country, alarmed by the enormous and rapid inflation of credits and under the advice and counsel of the Federal Reserve authorities at Washington, decided about a year ago to make an effort to hold this inflation in check.

The Dangers of Prosperity

Some people think, apparently, that a bank can grant any amount of credit, but it cannot do so. A bank is not a creator of wealth in the sense that a factory or a farm is; it is a reservoir of the liquid wealth of the community. It receives what is put into it and, under a sound banking policy, somebody must put into a bank every dollar that is paid out. Beyond that, all landmarks and guideposts are lost; there is no guide except the demand for money. The great trouble with our people is that they do not realize the danger of a great body of indebtedness on a high level of prices. They do not stop to think that, while their assets may shrink rapidly, their debts will not shrink at all. In Iowa, where the people have been exceedingly prosperous in recent years, if anybody had been able to predict the amount of money that they would receive for their products in the next 5 years, and if that prophet had never read history and did not know anything about human nature, he probably would have said that at the end of 5 years they would all be out of debt. The Department of Agriculture at Washington made an inquiry into the value of farm lands in Iowa last spring. It was found that the average value of all the lands in the State had increased $63 an acre from March 1919 to March 1920. The people of Iowa felt that they were prosperous and that they were entitled to credit. They proceeded to use it. The Federal Reserve Bank at Chicago recently made the statement that its loans within the State of Iowa were at that time 247 per cent of the normal quota which the State was entitled to.

In Cuba, there never had been such a state of prosperity as there was in the last 5 years. One might think that Cuba would get entirely out of debt and be rich ever after. Today, the people of Cuba are living under a moratarium established to relieve them of the necessity of paying their debts, this having been done to save the credit situation from a complete collapse. The fact is that people never use the earnings of good times to pay their debts. They use their earnings as the basis for further borrowing. They make their debts in good times and pay them under pressure in hard times.

Present Situation and Outlook

Although there is a period of quiet business while an adjustment is being made, the situation of this country is remarkably good considering the experience through which it has passed and the readjustments which were absolutely necessary. It has developed that the general condition of the business community is good, under all the circumstances, and in some respects very favorable to early recovery. In the past, in every similar situation, the reaction in business has come after a period of expansion under which a great amount of development and construction work had been done in the country, after a period of railroad building, of general city building and of over-expansion in that direction. That is not the situation at this time. We have had this period of expan-

sion, not because of construction work of that kind, but because of our expenditures upon the war. It was stimulated largely by the war business, and the fact is that this country is under-built today. There is a great backed-up demand for development and for construction work, which will speedily be done if the general conditions in industry are made favorable to do it. The railroads of this country need to spend literally billions of dollars to bring their capacity up to the needs of the country. A great house-building campaign should be carried on. The automobile business is behind the development it would have had except for curtailment during the war.

I reiterate that the industries of the country must be brought back into balance. Industrial costs must be lowered; construction costs must be lowered before we can hope for a general and complete revival of business. There is an obligation upon every class interested in prosperity to look the situation squarely in the face and see what part each individual ought to perform in bringing about this necessary readjustment.

THE PACKARD FUELIZER

(*Concluded from page* 248)

the reason it is important to insure a correct mixture. The later forms of fuelizer show an improvement in that respect. It is reasonable to suppose that the driver will adjust his mixture control to obtain the best mixture.

A MEMBER:—If carbon is deposited on the screen, can it be burned off with a different mixture?

MR. WOOLSON:—No, but it can be scraped off. The screen may require cleaning every six or seven months, but with the correct mixture it will run indefinitely.

A MEMBER:—Does the heat transmitted through the fuelizer walls or that contained in the burnt gases do the most good?

MR. WOOLSON:—Both sources are used about equally.

A MEMBER:—Is there no volumetric sacrifice?

MR. WOOLSON:—Not with a wide-open throttle. As soon as the throttle is opened wide enough, the flame goes out.

A MEMBER:—Is there any difficulty due to oxidation of the screen?

MR. WOOLSON:—No, it is made of ordinary brass.

A. J. SCAIFE:—Is the screen used on the new design?

MR. WOOLSON:—Yes.

E. W. WEAVER:—I note the infinitesimally small hole for the passage of the gas. Does that hole become clogged?

MR. WOOLSON:—The only time it becomes clogged is during its manufacture. In the beginning we had to inspect it and supervise the washing process to get the chips out. It gives practically no trouble in the car. The bottom of the vaporizer is only ¾ in. below the level of the gasoline in the float-chamber; the remaining distance is 1½ in. The tendency is to keep particles away from that hole; furthermore, the gasoline is entering the float-chamber and 95 per cent is supplied to the main jet. There is every chance that the main jet will get the obstructions.

A MEMBER:—Is any trouble caused by dust?

MR. WOOLSON:—We have had no trouble from that source. We locate the air inlet where we think there is no dust. Many persons thought we would have trouble with dirt, but that has not been the case.

A MEMBER:—Can this fuelizer be applied when kerosene is used for fuel?

MR. WOOLSON:—I have run on kerosene repeatedly. It will run on kerosene, but I believe it cannot be made to start. It might be possible to start with kerosene by using electric heating methods, but the ordinary way is to start on gasoline and then turn on kerosene.

A MEMBER:—Can more heat be provided?

MR. WOOLSON:—Yes, but we are not doing that now.

A MEMBER:—If heat were supplied, would the fact that an inert gas is used cut down detonation?

MR. WOOLSON:—I think it would, but it is something that is associated with a wide-open throttle. That is the wrong way to kill detonation; it kills the engine power. It must be cured in a way that will increase the engine power.

A MEMBER:—What is the temperature of the gas in the manifold while idling?

MR. WOOLSON:—That depends upon how long the engine idles. It will get extremely hot in time. We have had so much heat on the manifold that the thermometer registered from 200 to 400 deg. fahr.

DILUTION OF CRANKCASE OIL

(*Concluded from page* 237)

was no further trouble. I hope that the automotive industry can face the difficulty in the same way. I have an example in a six-cylinder car that has been sold in very large quantities. One of these cars ran about 14 miles per gal. of gasoline, and used a large quantity of oil. The owner replaced the rings and saw that they were properly fitted on the pistons. He obtained a slight improvement in the gasoline consumption and a great improvement in that of oil. After running the car several months that way, he dismantled the engine, ground the cylinders to a true, round condition and replaced the piston-rings; the fuel consumption was reduced to 20 miles per gal. of gasoline and the oil consumption was reduced two-thirds.

I discussed this question of grinding cylinders with a maker of quantity-production cars. He said that it can be done for less than $1 per cylinder. Unfortunately, when the American owner begins to economize, he begins to economize on the first cost. Very few people in this country buy for quality and for the long pull; until they do, we will have the difficulty that what is right from an engineering and from the long-pull point of view costs somewhat more at first and makes a greater sales resistance. The same condition is met in the oil industry. I feel that the engineers of the automotive industry must design and build for the long haul and for economy so far as their commercial and sales departments will permit them to do so.

Need for Researches on Automobile Parts

By William T. Magruder[1]

Annual Meeting Paper

THE work of automobile testing laboratories has largely followed the example set in the last 40 yr. by steam-power laboratories. Tests on engines and materials have become common, while high-grade tests of fuels have been made only in a very few research laboratories. Tests on some one appliance have been made and the results buried and forgotten in the archives of the manufacturer of the particular appliance without their being made known to the automobile world. The time has now come when greater attention must be given to the smaller parts and to the various appliances found on automotive machinery.

Previously investigations have been made by the research laboratories of a few companies manufacturing engines, carbureters and a few other parts, but chiefly of engines; of research corporations, including the Bureau of Standards and the Bureau of Mines of the Federal Government; and of the engineering laboratories of our colleges of engineering and technical schools. It is hardly to be expected that private research laboratories should give to the world, even through this Society, the results of experiments which have cost from one to several hundred thousand dollars per annum, although it must be admitted that they have erred on the side of generosity rather than of selfishness in this regard. The number and value of the researches which can be conducted and reported on from time to time by Federal and State-supported institutions and universities depends entirely upon the appropriations that they can obtain by act of legislation and upon the personnel of the men attracted by the opportunity to do this class of work. It would therefore seem to be to the interest of the members of this Society to advance the research work being done by Federal and State institutions, and to see to it that adequate appropriations are made by our Congress and the General Assemblies of our states, and that those problems which most greatly need solution should be attacked first and all according to a guided program.

Research work in the engineering laboratories of state universities is done either by the instructors for their own interest and pleasure, or for their clients, or by the students as thesis work under the direction of one of the instructors. For these purposes, manufacturers are usually very generous in supplying material, if the laboratory will supply the testing equipment, fuel and labor. The colleges are glad to get this assistance even if the agreement is not always 50-50, and more frequently is 20-80, as it keeps them in touch with the manufacturing world.

Engine Tests at Ohio State University

In the last 20 yr. a number of tests of automotive machinery and parts have been made in the Mechanical Engineering Laboratory of the Ohio State University. It is thought that an outline of some of these tests may be of interest to the members of the Society in connection with this discussion of the subject. The friction of the engine can be determined by running an engine under load, absorbing the power by an electric dynamometer, and, when it has become thoroughly heated up, closing the throttle and carbureter valves and driving the engine from the dynamometer as a motor, and measuring the power required to drive the engine at various speeds, with and without the magneto, fan, valve-gear, or pistons. For example, it is of interest to learn that it requires about 2.5 hp. to drive a Ford engine at 700 r.p.m.; 3.0 hp. at 900 r.p.m., or at 22 m.p.h.; 3.5 hp. at 1000 r.p.m.; and 4.2 hp. at 1100 r.p.m., without current being generated by the magneto. With current from the magneto, from 0.2 to 0.3 hp. additional is required. That these results are low, as should be expected, as compared with the frictional horsepower developed when the engine generates its own power, can be shown by the statement that the frictional horsepower of a Ford engine, as determined by a number of different operators, varies from 4.5 to 4.7 hp. at speeds of from 800 to 900 r.p.m. These results were obtained by equating the pounds of fuel per indicated horsepower per hour at a given speed and for different loads, where the indicated horsepower is the sum of the measured brake horsepower and the unknown frictional horsepower, and solving for the frictional horsepower. With this figure available, the mechanical efficiency of the engine can be obtained with an accuracy depending upon the accuracy of the work and the correctness of the assumption, and will vary with the newness and tightness of the parts and how well they have been run-in.

The temperature of the jacket water of a certain water-cooled, four-cylinder engine was found to have a very decided effect upon both the operation and the power of the engine. Due to the intake mixture being preheated by partial contact with the exhaust manifold, preignition began, with gasoline as the fuel, when the inlet jacket water reached a temperature of 175 deg. fahr., became excessive at 190 deg., and caused a great reduction in power when the inlet water was 210 deg. The radiator cooled the water only by virtue of the fan and not by the car passing through the air, as in practice. By passing cold water in at the top of the radiator and drawing some of the warm water off at the bottom, thereby keeping the temperature of the outlet cooling water at 150 deg. fahr., it was possible to increase the power of the engine from 17.26 hp. to 18.26 hp., while increasing the gasoline consumption from 0.669 to 0.685 lb. per hp-hr. With kerosene, preignition began at 135 deg. fahr. By excess cooling, the maximum horsepower of the engine with kerosene under normal conditions was increased from 16.67 hp., using 0.89 lb. per hp-hr. to 19.36 hp., using 0.91 lb. per hp-hr. Excessive use of fuel caused this engine to give 18.41 hp., using 1.520 lb. of gasoline per hp-hr.; while with kerosene the maximum power was increased to 19.40 hp. when using 1.436 lb. per hp-hr. This means that 61 per cent more kerosene used gave 16.1 per cent more power, and that 127 per cent more gasoline used gave 6.6 per cent more power.

The maximum horsepower of this engine was 22.64 at a speed of 1043 r.p.m., when using 1.110 lb. of kerosene per hp-hr., and 21.07 hp. at 1020 r.p.m., when using 0.725 lb. of gasoline. The use of an excessively hot

[1]Aff. Rep. S. A. E.—Professor of mechanical engineering, Ohio State University, Columbus, Ohio.

manifold on this engine caused the maximum horsepower to change from 21.6, when the manifold was cool, to 16.1 hp. when the manifold became heated. This is a change of 5.5 hp., or a drop in power of 25 per cent. These results may be due in part to the tests being made in an open laboratory rather than on the road, but they seem to point to the desirability of having larger radiating surface than was provided with this engine. Again, numerous tests go to show that the proper jacket-outlet temperature for maximum power and minimum fuel consumption is a function of the shape and fit of the pistons and rings and the thickness of the jacket-water space.

Power Tests

The power lost in the transmission has been determined in this laboratory in two ways. The first is by measuring the speed-drop for increased loads for fixed settings of the carbureter needle-valve, throttle-valve, timer, and other variables, and noting the decrease in speed when power was delivered through the transmission, rather than by the engine direct. By this method, the speed of the engine dropped from 900 to 869 r.p.m., corresponding to 1.35 hp., when the fan was used; and from 900 to 769 r.p.m., corresponding to 3.30 hp., when the transmission was used. Second, by comparing the horsepower delivered by the engine alone to the horsepower delivered through the transmission to the belt-pulley of the tractor, and measured by the brake pulley, the loss between the engine and the pulley was found to be 3.25 hp., or 16.75 per cent of the maximum normal power of the engine. This result checks quite closely with the former. A third method, not yet used, is to insert a torsion dynamometer between the transmission and the differential, or between the engine and the transmission, when this is possible.

The power delivered by the rear wheels is best measured by mounting the machine on calibrated dynamometer brake-drums. When the rear wheels are replaced by special brake pulleys, an unknown allowance should be made for the frictional load due to the weight of the car on the wheels. A third way that has been tried with fair satisfaction is to replace the rear wheels by sprocket wheels and drive the chain pinions on the ends of the electric dynamometer shaft by chains or link belts. In this case what is measured is not the power delivered by the wheels, but the power delivered by the chains, and this varies with different speeds and loads. When due allowance is made therefor, very satisfactory results can be obtained in measuring the power required to drive certain parts under a variety of conditions, including those with and without compression in the cylinders. A fourth method, usually used in tractor testing, is to absorb the power from the belt-pulley delivered by a belt to an absorption dynamometer. As in the previous cases, allowances must be made for the power required to drive the belt and the dynamometer at different speeds, at initial tensions and whether the belt is open or crossed. In tractor plowing under quantitative test conditions, it has been noticed that only a small decrease in speed will cause the sod to be turned over very differently and without being pulverized, so that a difference of 10 per cent in speed will turn good plowing into bad.

Springing of the Chassis

We have been prevented financially from testing a motor car under its own power when mounted on calibrated dynamometer brake-drums having very irregular surfaces, simulating the effects of cobble-stones on the springs, and measuring the power required to drive the car at different speeds on brake-drums of varying roughness. In the scheme proposed, rays of light were to be reflected from mirrors on the wheel hubcap and on some part of the car above the springs, and received on sensitized paper, to show the relative emotions of the two parts of the car.

The trustees of the Ohio State University are asking the State Legislature of Ohio for an appropriation of $80,000 for an addition to its present mechanical engineering laboratory building, so as to care for the instructional and research work in automotive engineering. It is requested that all members of this Society from Ohio, and those having Ohio interests and connections, use, if they feel so disposed, their influence as citizens and taxpayers in the next few months to secure an adequate appropriation for the benefit of those students who desire to get professional instruction and experience in automotive engineering, rather than in some one other branch of engineering.

ECONOMICAL SIZE OF FARM

THE small farmer, generally speaking, works under a great many handicaps as compared with the farmer having a larger acreage. Students of the farm management and economics have known for a long time that, other things being equal, the returns from a farm business are practically in direct proportion to the size of the farm; that is, the larger the farm, the greater the net income. Of course it is easy to go too far in trying to farm a large acreage and do such a poor quality of work that the crop suffers. It is not meant to recommend this sort of practice but merely to show that frequently time can be spent better on additional acres than on overpreparation of a smaller acreage. The best solution of the small farmer's problems is to increase his acreage to permit him to utilize his labor and that of his hired hands to the best advantage through the use of large and efficient machines and at the same time keep the overhead charge, due to investment, etc., at a minimum figure. —A. P. Yerkes in *Power Farming*.

NUMBER OF FATAL AUTOMOBILE ACCIDENTS

THE National Safety Council has secured statistics from its 41 local branches and the 8000 industrial plants, trade organizations and Government agencies included in its membership. These indicate that the 80,000 deaths caused by accidents in 1919 should be divided as follows:

Home and Public Accidents, other than automobile	47,000
Industrial Accidents	22,000
Automobile Accidents	11,000

While a condition under which half as many persons are killed in automobile accidents as in all industrial accidents is a very serious matter and one deserving the earnest consideration of the entire country and more especially every branch of the automobile industry, the National Safety Council feels that a very great injustice is being done that industry through the circulation of exaggerated statements concerning the number of persons killed in the year 1919 by automobile accidents.

Need for Greater Service Accessibility in Car Design

By T. F. CULLEN[1]

CHICAGO TRUCK AND TRACTOR MEETING PAPER *Illustrated with* DRAWINGS

FOR years past we have been designing cars for production accessibility, in other words, so that the various parts could be made and assembled at the lowest cost. Complaints are frequently heard, however, to the effect that a great many cars are not as accessible as they might be for service work, notwithstanding they may be 100 per cent accessible for assembly at the factory. As a car is assembled only once at the factory, however, and is certain to be disassembled and put together again, in varying degree, a great many times in the service stations of the country, it is important that this subject of service accessibility receive greater attention.

Many of us are prone to overlook the fact that upon the car owner's satisfaction depends the success of both factory and dealer. The car owner is the man who pays all the factory salaries, other expenses and profits; he is the man we are all working for, though we may not all realize it. Everything that can be done to reduce upkeep and the maintenance cost of the car will tend to increase the owner's satisfaction. Of the various items of expense in connection with maintaining a car, depreciation is probably the largest single one, especially during the first year or two of the car's life. Insurance, garage expense, repairs and adjustments, tires, gasoline and oil follow in about the order given. Improved service accessibility would tend to reduce repair and adjustment costs by decreasing the amount of repair labor for any operations that are necessary from time to time, and would also tend to retard depreciation by enabling the owner to keep his car in good running order at a minimum expense. Moreover, the fact that a car is unusually accessible for all classes of repair work will enhance its resale value as a used car.

Every unnecessary complication in car design adds to the time required for necessary service work, and therefore robs the car owner of just that much money sooner or later. Greater accessibility for service work also tends to lengthen the life of the car, as it makes service work easier to perform, less costly and therefore more likely to be undertaken at the first indication of trouble. The supply of skilled mechanics is never large enough to fill the demand. Any improvement, such as better service accessibility, which cuts down the time per operation in service work without impairing the car's subsequent efficiency, has exactly the same effect as increasing the number of skilled mechanics. With more accessible cars, service stations could turn out more work with fewer mechanics and therefore make bigger profits, or show a profit where they now show a loss, as many of them do. The dealer's success, both in selling cars and in servicing them, is just as essential to the factory as the owner's satisfaction.

More and more cars are sold each succeeding year to replace worn-out vehicles. Service reputation, based on the cars now in use, is rapidly becoming the predominating factor in these resales. Therefore anything that can be done to improve service work will make resales easier in future. As an example of the results which could be secured by improving service accessibility, it is only necessary to recall that there are over 8,000,000 cars in use today, and improved design which would reduce the time necessary for service work to the extent of only 2 hr. per car per year, would save the owners over $15,000,000 per year on upkeep.

STATUS OF CAR DESIGN FOR SERVICE ACCESSIBILITY

Before attempting to point out how car design can be improved in the direction of greater service accessibility, it is necessary to know where we stand now. For this purpose I made a survey of 40 representative cars of all types and schools of design, including 4 and 6-cylinder and V-type 8 and 12-cylinder engines, and covering a wide price range. These cars were rated according to their comparative accessibility for 25 typical service operations, consisting principally of such operations as are likely to be required a number of times per year on the average car, together with a few operations which might be needed occasionally as the result of accident or worn or broken parts. No attempt was made to cover all operations or extensive overhauls. Each make of car was rated on the basis of 100 points for the most accessible design possible for all 25 of these typical operations or four points for the best design for each operation. A tabulated list of these 25 service operations, together with the ratings of the different cars, and the average rating of all cars and groups, is presented on pages 258 and 259.

Note that some of these service jobs required much less time than others but those taking the least time must be performed most frequently in the ordinary course of events, so that this method of rating gives very fair results for purposes of comparison. Where certain operations are not required on some makes of cars due to their design, the remaining operations were prorated. Accessibility of the car for these various operations was the only factor considered in rating the different cars. The ratings given were arbitrary, depending on the necessity, or otherwise, of removing other parts to get at those affected, the need of special tools, awkward position of the mechanic, etc. For obvious reasons, the names of the cars are omitted from this table, the different makes being referred to by number only.

It will be evident on studying this table that there is considerable room for improvement in service accessibility of the average car with respect to most of the operations covered in this survey, and the natural inference is that there is at least an equal opportunity for improvement with respect to other service operations. On a few operations the average ratings for all cars were

[1] A. S. A. E.—Managing editor, *Automobile Trade Journal*, Philadelphia.

COMPARATIVE SERVICE ACCESSIBILITY OF 40 REPRESENTATIVE

Operation Number	OPERATION	FOUR-CYLINDER CARS													SIX-CYLINDER CARS						
	Car Reference Numbers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Test battery or remove and replace	4	1	4	4	3	4	4	3	4	3	3	3	4	4	3	1	4	1	2	3
2	Tighten fan-belt	3	4	4	4	4	4	3	4	3	4	4	3	4	4	3	2	4	..	4	4
3	Paint springs with graphite and oil	4	4	3	4	1	4	3	5	4	4	4	4	4	2	3	3	1	4	4	4
4	Flush crankcase and refill	3	3	4	4	4	4	4	4	4	4	4	4	4	1	4	4	4	4	4	4
5	Tighten spring clips	3	4	3	4	3	4	4	4	3	4	4	3	3	3	4	4	4	1	4	4
6	Clean out gasoline line	3	4	3	3	3	4	4	4	4	4	2	2	4	3	2	2	3	4	3	3
7	Repack water-pump	2	4	..	..	..	1	..	..	2	..	1	4	4	4	..	4	4	.	4	3
8	Replace all hose connections	4	2	4	4	3	2	1	3	4	4	4	3	3	4	2	2	4	.	2	2
9	Adjust brake bands and pull-rods	4	3	3	3	3	4	3	3	3	3	3	3	4	4	2	3	3	1	1	1
10	Install and sand in new generator brushes	3	4	2	3	3	3	3	3	3	2	3	2	3	2	2	2	2	3	4	4
11	Replace and adjust breaker points	3	4	4	4	2	4	3	4	4	4	1	4	4	3	4	3	3	2	4	1
12	Clean oil-pump intake	4	4	4	4	1	4	3	2	1	4	1	4	4	2	4	3	4	4	4	4
13	Adjust clutch	1	3	4	3	3	3	3	3	1	2	1	3	4	3	2	4	4	3	4	3
14	Replace fan-belt	4	4	4	4	3	4	4	4	4	1	2	4	4	4	2	2	4	..	4	4
15	Grind valves and remove carbon	4	4	4	4	4	4	4	3	4	2	4	2	4	2	4	1	4	1	2	1
16	Remove and replace carburetor	4	3	4	4	3	4	4	4	4	3	4	3	4	2	3	3	3	3	3	1
17	Remove and replace generator	2	4	4	3	3	3	3	4	1	1	1	3	4	3	3	4	3	3	2	1
18	Adjust steering gear—remove play in wheel	1	4	3	4	1	4	4	4	4	2	3	4	4	4	2	4	4	3	4	4
19	Reline all brakes	4	3	4	3	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
20	Adjust engine front end drive	3	2	4	3	3	4	2	2	2	2	4	4	4	2	3	3	4	1	1	3
21	Remove and replace starting motor	3		2	2	1	2	4	1	2	1	4	1	4		1	2	4	.	2	.
22	Replace one piston	2	1	3	4	4	4	1	4	3	4	4	2	4	2	4	1	4	1	3	4
23	Tighten one connecting-rod bearing	2	1	3	4	4	4	3	4	2	4	4	4	4	4	4	4	4	2	4	1
24	Install new rear spring or lower half	4	4	4	4	4	4	3	4	2	1	4	4	3	2	3	3	2	3	4	4
25	Replace cam-shaft	3	2	2	3	4	4	1	2	2	1	4	3	4	3	3	3	4	3	4	3
	Average per Car All Operations	77.00	82.29	86.46	89.58	73.96	89.00	82.29	85.42	79.00	72.92	88.00	79.00	95.00	75.00	72.92	70.00	89.00	76.25	84.00	88.54
	Price Class	Under $1,000	$1,000 to $1,500	$1,000 to $1,500	$1,500 to $2,000	Under $1,000	$2,500 to $3,000	$1,500 to $2,000	Under $1,000	$1,000 to $1,500	Under $1,000	$1,500 to $2,000	Above $2,000	Above $2,000	$1,500 to $2,000	$1,500 to $2,000	$1,500 to $2,000	$1,000 to $1,500	$2,500 to $3,000	$2,500 to $3,000	$2,000 to $2,500

very high and the individual ratings practically uniform. On some other operations, however, such as cleaning out the gasoline line, replacing hose connections, removing and replacing the carbureter and the generator, adjusting engine front-end drive, etc., there was considerable variation. The lack of uniformity between different operations on the same car, showing that cars which are quite good in some respects are radically inaccessible in others, should also be noted.

As might be expected, the four and six-cylinder cars show very nearly the same average values throughout, while those with V-type engines are, on account of their design, less accessible for certain operations around the engine. This does not necessarily indicate any serious defect in the V-type engine, as other factors not directly related to service work must be taken into account in determining the all-around desirability of any type of car; it is only the accessibility for service work that is being considered in this paper.

The cars covered by this survey include practically all price classes, but they are not arranged according to their selling price. For further aid in making comparisons, the price range on each car is given in this table. It is noteworthy that some of the lower-priced cars show up better in this survey than some of their more costly brothers, indicating that accessibility as it affects service work is not connected in any way with price. A low-priced car is usually simple in design, containing the minimum of parts, and it can therefore be made very accessible for service work. On the other hand, it may be very inaccessible, not because of a multiplicity of parts, but because the parts are not placed to the best advantage. In the higher-priced cars even a large number of parts

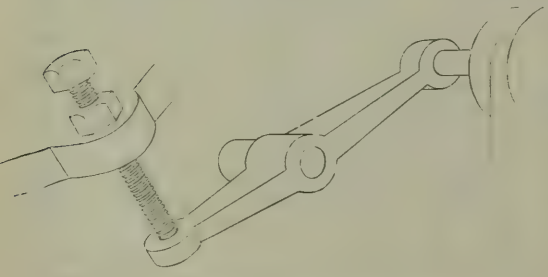


FIG. 1—A VERY SIMPLE TYPE OF FAN-BELT ADJUSTMENT

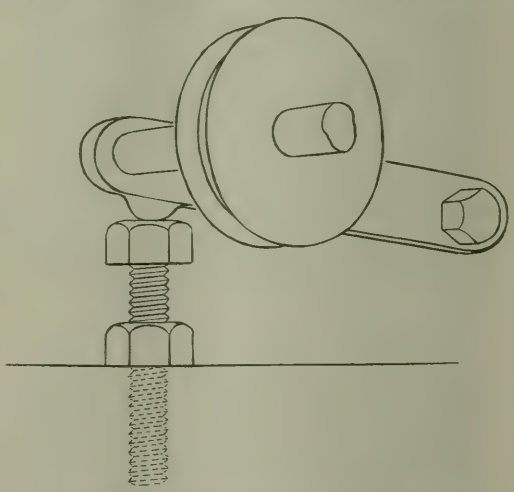


FIG. 2—ANOTHER TYPE OF FAN-BELT ADJUSTMENT WHICH IS CONSIDERED ALMOST AS GOOD AS THAT SHOWN IN FIG. 1 EXCEPT THAT THE ADJUSTING SCREW CANNOT BE TURNED WITH A SPEED WRENCH

CARS ON 25 TYPICAL SERVICE OPERATIONS

SIX-CYLINDER CARS														8 AND 12-CYLINDER CARS—V-TYPE						AVERAGES			
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	All Cars	Four-Cylinder	Six-Cylinder	V-Types
[illegible]	3	3	3	4	4	4	[illegible]	4	[illegible]	4	4	4	3	3	4	4	4	[illegible]	3	86.90	90.40	84.50	87.50
4	3	4	4	4	3	3	3	3	[illegible]	4	3	4	4	.	4	4	1	..	..	88.20	92.30	87.50	75.00
[illegible]	4	[illegible]	3	4	3	4	4	4	[illegible]	4	4	3	4	4	4	4	4	2	4	91.90	94.20	90.50	91.70
[illegible]	4	4	4	3	4	4	[illegible]	3	4	4	[illegible]	3	4	3	[illegible]	[illegible]	[illegible]	[illegible]	4	95.00	96.10	95.20	91.70
[illegible]	4	4	3	3	4	4	4	4	4	4	4	4	4	4	4	3	4	3	4	93.10	88.50	86.40	91.70
2	2	4	4	4	4	4	1	4	2	4	2	[illegible]	4	3	1	3	4	2	4	78.75	84.60	77.40	70.80
4	4	..	4	1	1	2	2	3	[illegible]	[illegible]	..	3	2	1	2	2	4	[illegible]	3	72.50	75.00	76.50	58.30
[illegible]	[illegible]	3	3	3	4	3	4	4	1	4	4	[illegible]	[illegible]	1	[illegible]	4	4	2	2	80.10	84.60	80.00	70.80
3	[illegible]	4	4	[illegible]	3	3	3	3	2	3	3	3	[illegible]	3	3	3	3	3	3	78.10	80.80	77.40	75.00
3	3	[illegible]	3	[illegible]	3	3	3	3	2	3	3	3	3	3	3	3	3	3	[illegible]	71.90	71.20	71.40	75.00
[illegible]	4	[illegible]	3	4	4	4	4	4	4	3	[illegible]	4	1	3	4	[illegible]	4	2	2	85.60	86.50	86.90	79.20
[illegible]	[illegible]	4	4	2	3	4	4	4	4	4	4	4	4	2	2	4	[illegible]	[illegible]	4	87.50	82.70	91.70	83.30
4	[illegible]	4	3	3	3	4	3	4	4	3	4	3	3	[illegible]	2	3	3	3	3	80.00	76.90	84.50	70.80
4	3	2	2	2	4	4	4	[illegible]	4	3	[illegible]	2	4	..	4	4	2	..	..	83.30	88.50	80.00	83.30
[illegible]	4	4	3	[illegible]	4	4	4	[illegible]	[illegible]	4	4	4	2	2	2	2	1	1	1	79.40	90.40	84.50	37.50
3	4	3	3	[illegible]	4	3	4	4	[illegible]	2	4	4	4	2	3	2	2	2	2	82.50	92.30	84 50	54.20
3	3	2	3	[illegible]	4	[illegible]	4	3	2	3	4	4	4	1	4	4	2	3	2	78.75	80.80	81.00	66.70
4	3	4	4	2	4	4	4	[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	2	4	3	3	3	2	85 00	80.80	91.70	70.80
3	3	[illegible]	[illegible]	3	4	[illegible]	3	3	3	3	3	3	3	3	3	3	3	[illegible]	3	76.25	75.00	77.40	75.00
2	2	2	4	[illegible]	1	2	2	2	2	4	3	2	4	4	[illegible]	2	3	2	1	68.75	75.00	69.00	54.20
3	2	[illegible]	2	4	4	4	[illegible]	4	4	3	4	2	4	.	2	2	3	[illegible]	3	70.00	62.50	76.40	54.20
4	3	[illegible]	2	4	3	[illegible]	4	4	3	4	4	4	4	3	2	3	3	1	1	77.50	80.80	82.10	54.20
[illegible]	3	4	4	[illegible]	2	4	[illegible]	4	3	4	4	4	[illegible]	3	2	3	3	2	3	85.60	82.70	92.90	66.70
4	4	[illegible]	2	4	[illegible]	4	5	4	4	4	4	4	4	3	4	1	[illegible]	2	4	87.50	92.30	88.10	75.00
2	[illegible]	2	4	3	2	[illegible]	3	3	2	4	[illegible]	3	2	1	1	1	1	1	1	64.40	67.30	73.80	25 00
87 00	83.00	86.46	81.00	82 00	83.00	89.00	84.00	89.00	80 00	88 00	89 58	86 00	85 00	64.77	72 00	75.00	76.00	60.87	67 39	81.30	83.10	83 30	69.60
$3,000 $3,500	$2,500 $3,000	$1,500 $2,000	Above $5,000	Above $5,000	$1,500 $2,000	$1,000 $1,500	$1,000 $1,500	$2,500 $3,000	$1,500 $2,000	Above $5,000	$2,000 $2,500	$1,000 $1,500	$4,500 $5,000										

need not seriously affect the service accessibility of the design.

Possible Improvements Suggested by Survey

During the course of this investigation many noteworthy designs were observed and in the accompanying sketches some attempt has been made to outline various designs which could be used without copying from any particular make of car. None of these sketches was made from any one make of car, but rather they are composites incorporating the best features as regards

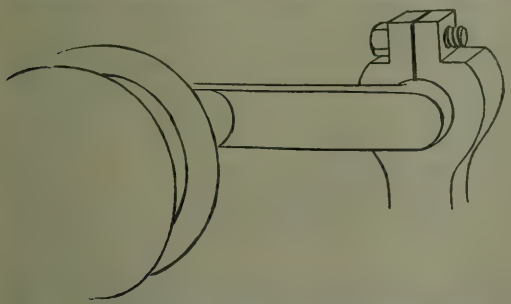


Fig. 3—In This Type of Adjustment the Fan Bracket Must Be Held in Position by a Special Tool while the Locking Screw Is Being Tightened

designing for service accessibility in the various cars examined. The illustrations cover only a few of the points taken up in the foregoing discussion that can be clearly illustrated. No attempt will be made to take up the location of parts of the car other than those connected with the survey already referred to. Even on these 25 operations, however, there are many little points in connection with designing for service accessibility that are worthy of mention.

In connection with operation No. 1, for instance, it developed that the most accessible location for the storage battery is under the right front floor-boards or under the right front seat. The battery is inspected very frequently and in many instances at a battery service station which has no garage facilities, so that the work must be done while the car is standing at the curb. Locating the battery on the right side of the car is therefore good practice from this standpoint. In a sedan with no front door on the right side, the best location for the battery seems to be under the rear floor, preferably near the right side of the car. It is hardly necessary to add that the terminal connections should be accessible, so that they can be broken with an ordinary open-end wrench, and the holding-down clips should be as simple as possible, preferably of the spring or wing-nut type.

In fan-belt adjustments there are several different designs which are giving good results in service. Fig. 1 shows a type of adjustment which has much to recommend it. The adjusting screw can be turned either with an open-end or a socket wrench, preferably the latter for

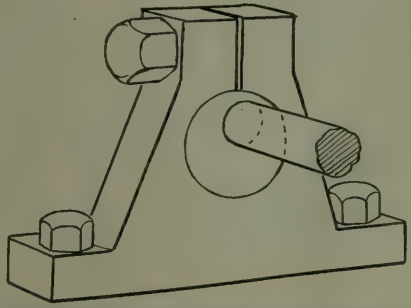


Fig. 4—An Eccentric Type of Fan-Belt Adjustment Usually Requiring a Large Wrench or a Special Spanner To Turn It

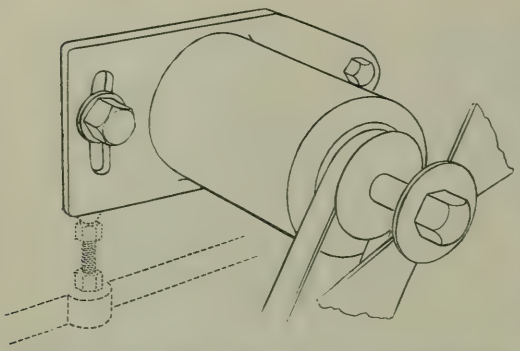


FIG. 5—MOUNTING FOR A BELT-DRIVEN GENERATOR IN WHICH EASE OF ADJUSTMENT IS SECURED BY PIVOTING THE BASE PLATE AT ONE END AND PROVIDING A SLOTTED ADJUSTMENT AT THE OTHER
An Adjusting Screw as Shown by the Dotted Lines Would Be an Improvement

speed. The adjusting screw should be easily accessible so that the lock-nut can be loosened readily. Probably it would be best to locate this adjustment so that the work can be done from the right side of the car, with the adjusting screw set at an angle as shown. Figs. 2, 3 and 4 on pages 258 and 259 show other types of fan-belt adjustment which also give good results, although I do not consider them quite the equal of that shown in Fig. 1 on page 258. With the adjustment shown in Fig. 2, for instance, it is necessary to turn the adjusting screw with an open-end wrench, and very often there is only a limited space in which to swing the wrench, owing to the proximity of the fan belt and blades. The principal objection to the adjustment shown in Fig. 3 is that the bracket or arm on which the fan shaft is mounted must be held in position either by hand or with a special tool, while the clamping screw is tightened. For this reason it is best not to use a nut on the clamping screw but rather a lock washer under its head. It seems preferable to make this adjustment also from the right side of the car. The eccentric adjustment illustrated in Fig. 4 gives good results, but the range of adjustment is usually more limited than with the types previously mentioned. With this device also it

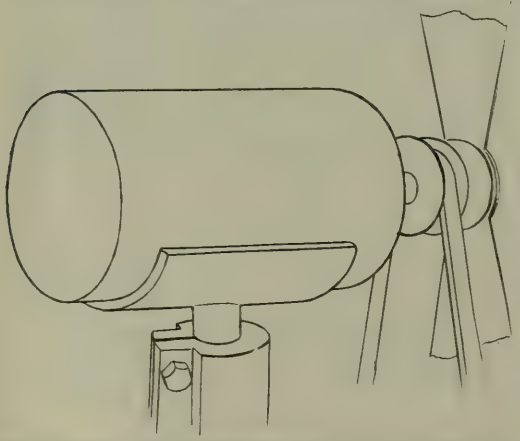


FIG. 6—ANOTHER TYPE OF MOUNTING WHICH IS OBJECTIONABLE BECAUSE THE GENERATOR MUST BE HELD IN POSITION EITHER BY HAND OR A SPECIAL TOOL WHILE THE CLAMPING SCREW IS TIGHTENED

is advisable to make the adjustment from the right side of the car, and to use a plain clamp screw with a lock washer under the head and no nut. Usually a large hexagon or castellated prongs are provided on the outer end of the eccentric to facilitate turning it. Perhaps a smaller hexagon, not more than ¾ in. across the flats, would be preferable, as a large wrench or special tool for turning the eccentric is not always available.

Figs. 5 and 6 illustrate two common methods of mounting a belt-driven generator with which the fan is incorporated. Fig. 5 shows the better method from the standpoint of service accessibility. Note that in this illustration the mounting plate of the generator is pivoted at one end, and a slot adjustment with clamping screw is used at the other end to hold the unit in place when the proper adjustment of the driving belt is obtained. An improvement might be made by locating an adjusting screw at some convenient point, as shown by dotted lines in this illustration. This would enable the mechanic to raise the generator easily to the proper point and hold it there while locking the adjustment. Without this added feature, it is necessary to loosen one or two clamping

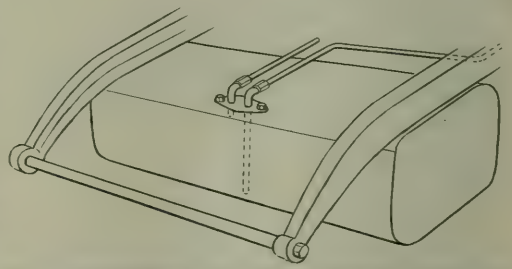


FIG. 7—THE GASOLINE TANK OUTLET CONNECTION SHOULD BE ACCESSIBLE FOR CLEANING THE FEED LINE
An Overhanging Body or Spare Wheels at the Rear Must Be Considered in Locating the Outlet

screws in the adjustment slots and raise the generator either by hand or with a special lifting bar, and hold it in place while tightening the clamping screws. This latter objection also applies to the type of adjustment illustrated in Fig. 6. The generator and fan assembly is a rather heavy unit to hold in place with one hand, or even with a special lifting bar, while tightening the adjustment. The position of the mechanic is sometimes awkward at best, and perhaps before he can get the clamping screws tightened enough to hold the unit in its proper position, it will slip down somewhat.

Front and rear spring clips can be located so that they can be tightened readily when necessary. The practice of placing the threaded ends of the rear spring clips upward with underslung rear springs is gradually being abandoned in favor of inverted U-shape clips passing over pads on the axle tube and projecting through cross plates under the spring. This puts the spring clip nuts below the spring where they are readily accessible, and is a step in the right direction.

Even such an operation as blowing out the gasoline line is difficult on some cars, due to the inaccessible location of the gasoline outlet connection from the rear tank, now used on the majority of models. Fig. 7 illustrates a type of connection which would appear to give the best results on the average car, except where the body overhangs the rear edge of the tank. In some designs no separate vent pipe is used, the vent hole being drilled in the filler cap. If spare wire wheels or disc wheels are

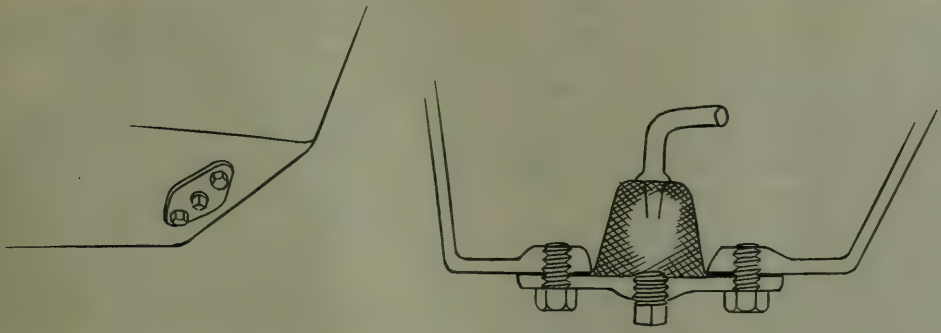


FIG. 8—COMBINING THE CRANKCASE DRAIN-PLUG WITH THE COVER-PLATE OVER THE PUMP INTAKE SCREEN SIMPLIFIES CONSTRUCTION

to be carried at the rear of the car, the gasoline outlet connection should be near one end of the tank and the filler-cap and gage near the other, so that it will not be necessary to disturb the spare wheel or wheels either in filling the tank or in cleaning out the gasoline line when clogged. The forward end of the feed line is usually accessible enough, as it is on top of the vacuum tank in a great many cases.

Water-pump packing-nuts are very inaccessible on many cars. They should be clear of the pump and not

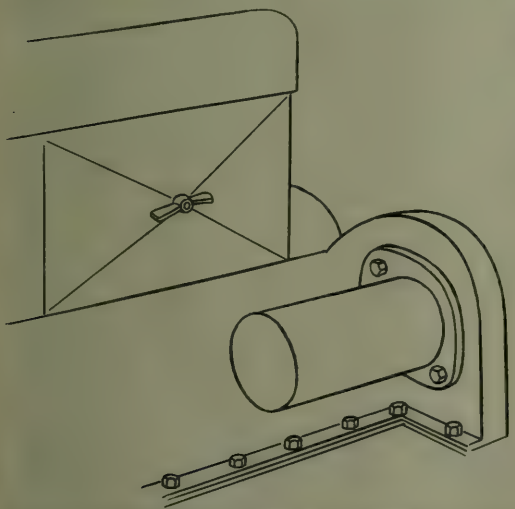


FIG. 9—AN ACCESSIBLE ATTACHMENT OF THE GENERATOR TO THE BACK OF THE TIMING GEAR CASE WHERE THE ENGINE USES A GEAR TRAIN IN THE FRONT END

made inaccessible by being placed too close to other units, such as the generator and ignition unit, or between the back of the pump and the cylinder casting, or the front gear housing. Sufficient room should be allowed so that the packing-nuts can be backed off and repacked readily when necessary.

Hose connections on different cars vary greatly as regards accessibility. Usually the upper hose is accessible enough, but the lower one may run under the forward crankcase arm or some of the other units around the front of the engine, making it very inaccessible for replacement. In some cars it is even necessary to remove the sod-pan to replace the lower hose. Where it is impossible to make this hose accessible in any other way, it would seem advisable to run it entirely under the sod-pan or provide a door in the latter.

Brake pull-rod adjustments could be made much simpler on a great many cars, first by placing the adjustments in the most accessible locations, second, by providing turnbuckles or other means of adjustment which could be altered without having to disconnect the pull-rod entirely. Where the rod must be disconnected to alter the adjustment, considerable time is consumed, as the alteration must be made, usually by the cut-and-try method, connecting up the pull-rod after each change and testing to see if it is correct.

The location of the oil-pump intake could be improved considerably from the standpoint of accessibility on a number of cars. Where the pump is located in the bottom of the crankcase, some such construction as that shown in Fig. 8 could be used. If the drain-plug is incorporated

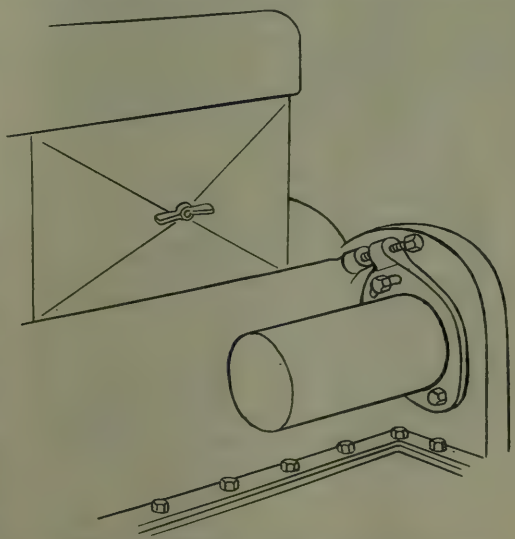


FIG. 10—GENERATOR MOUNTING FOR USE WITH A CHAIN DRIVE IN THE FRONT END OF THE ENGINE AND WHICH IS EMPLOYED AS A MEANS FOR TAKING UP SLACK IN THE CHAIN

in the cover-plate over the pump intake screen, it simplifies matters considerably. Where a separate sod-pan is used, a good sized hole should of course be cut in it directly under the drain-plug and pump screen cover-plate. This is done in a number of cars but frequently the hole is not as large as it should be.

Fan-belt replacement can be facilitated by allowing plenty of space around the lower pulley, so that the belt can be slipped over it without difficulty. Sometimes the front end of the sod-pan or the ratchet for the hand starting-crank, or some other parts, interfere to such an extent as to make it a difficult and tedious job to work a heavy fan-belt into place.

To facilitate valve-grinding and adjustment, the valve-stems and springs and adjusting screws should be unobstructed by other units, if possible. Sometimes lowering the generator an inch or two or setting the carbureter a little farther out from the cylinder block would make a really remarkable improvement in the accessibility of the valve-stem adjustments.

Generators can be mounted in various ways, but the schemes illustrated in Figs. 9 and 10 on page 261, together with those in Figs. 5 and 6 on page 260, will serve to illustrate some of the possibilities for accessible mountings. Where a train of gears is used in the front end of the engine and the generator is driven by a gear meshing with the camshaft gear or another one in the train, the mounting shown in Fig. 9 can be used. An important detail is to locate the cap-screws holding the generator flange in position on the gearcase so that both are readily accessible. Many constructions use three cap-screws for this purpose, and it is inevitable with this construction that one of them will be very inaccessible. If it is possible to get along with two, locating them about at the angle shown in Fig. 9, accessibility would be much improved. The mounting illustrated in Fig. 10 is, of course, for use with a chain drive in the front end of the engine, in which the generator mounting is used as a means of taking up the slack in the chain. The usual practice with this type of mounting is to pivot the generator flange on one cap-screw and provide one or two other cap-screws in slots in the flange, so that the generator can be moved slightly to take up slack in the chain, and then locked in position. The adjusting screw shown in Fig. 10 is a slight improvement, as it makes possible adjusting the chain while the engine is running, and then locking the generator in place when the proper adjustment has been obtained. The type of mounting shown in Fig. 9 might be used also for attaching the starting motor. If it is felt that more than two points of support are required, to take the torque of the motor, it might be possible to use two dowel-pins and two cap-screws on the mounting flange, the two cap-screws being located approximately in the positions shown in Fig. 9, and the dowel-pins 90 deg. away from the cap-screws.

The matter of accessibility of brakes is almost worthy of a book in itself. No attempt will be made to go into the subject very deeply here. There is one little kink, however, which might be adopted on a number of cars to simplify the removal and replacement of the external contracting brake-bands on the rear-hub drums when relining is necessary. This is the use of a special bolt instead of a riveted stud in the outer end of the brake torque-arm, as shown in Fig. 11. When a riveted stud or a projection integral with this brake arm is used, the only way to remove the brake-band is by pulling off the rear wheel and sliding the brake-band outward. By using a special bolt at this point, however, it is possible to remove the brake-band by springing it slightly, and without having to remove the wheel. Where one of the brakes is on the drive-shaft or back of the transmission, and only external brakes are used on the rear wheels, this construction might improve the service accessibility of the rear-wheel brake mounting. Even on cars using both internal and external rear-hub brakes, this construction might be advantageous. The outer or contracting brakes are usually the service brakes, and the inner expanding brakes the emergency set with this construction, and in the hands of the ordinary driver the service brakes are used much more than the emergency set and consequently may require relining about twice as often. On those occasions when only the outer or service brakes require relining, this construction would facilitate the work by making it unnecessary to remove the rear wheels to get at the brake-bands.

The remarks made previously with reference to generator mounting where the generator is used as a means of adjustment for a chain drive in the front end of the engine, cover one form of engine front-end adjustment which is generally used. If it is impractical to use the generator for adjusting a chain drive, however, some other means of adjustment, easily accessible from the outside of the gearcase, should be provided. Needless to say, it should not be necessary to remove any parts to get at this adjustment. Where gears are used for the engine front drive, no means of adjustment is required, but it will be necessary occasionally to replace worn gears or to install a new set to get quieter operation. Even though this work may be required only rarely, it is advisable to make the front-end drive of the engine as accessible as possible. Where a three-point support is used, with a single support in the front and the remaining two on the flywheel housing, it is usually necessary to block up the front end of the engine at the crankcase before removing the front gearcase cover, for the reason that the front support of the engine is very often integral with this cover. This difficulty is not encountered where the four-point support system is used. But even with the latter type of construction there are a number of cars on which it is necessary to remove various units such as water-pumps, and occasionally generators or magnetos, before the timing-gear cover can be taken off.

In tightening connecting-rods and replacing pistons most of the work must be done from underneath the car; therefore a separate sod-pan is a great inconvenience unless it can be removed very easily. The bolts or cap-screws holding the crankcase lower pan in place should all be as accessible as possible. Wherever it is necessary to locate these in narrow spaces, as, for instance, across the back end of the crankcase, just forward of the flywheel housing, where the space is so small that it is impossible to start these screws by hand, cap-screws with lock washers should be used; never round-head screws. A standard hexagon-head cap-screw can be inserted in place as well as tightened up with an ordinary brace socket-wrench, but it is extremely difficult to start a round-head screw in a narrow space.

Removable cylinder-heads, of course, facilitate piston removal and replacement, but even where the solid cylinder-heads are used it is seldom difficult to design the engine so that pistons can be removed and replaced from below in case of necessity. A slight bevel at the lower end of the cylinder bore will help matters considerably, as this will serve the purpose of compressing the piston-rings when placing the piston in the cylinder,

thus rendering a special piston-ring compressor or squeezer unnecessary.

The remarks made with reference to the engine front-end drive apply to camshaft removal and replacement. Accessibility for easy camshaft replacement requires that any auxiliary units, such as the igniter or the oil-pump, when driven off the camshaft, be connected in such a manner that they will not have to be dismounted before the camshaft can be pulled out through the front end. Also these auxiliary gears must mesh readily with their driving gears on the camshaft as the latter is replaced. They should mesh either ⅛ in. or so before the camshaft gear meshes with the crankshaft gear or ⅛ in. or more after the main timing-gears have been meshed. This is, of course, to avoid difficulty in meshing different sets of gears, which would be encountered if they all came into mesh about the same time. Of course, where the engine front drive is by chain, this difficulty is not encountered. Usually when gears are used it is feasible to mount the large timing-gear on the camshaft before replacing the latter in the engine, to insure that it will run true. That is why the meshing of the auxiliary-drive gears operated off the camshaft is brought up in this connection.

Spring breakages, especially of rear springs, are not as rare as we would like to see them. Therefore, the rear spring mounting particularly should be so designed that spring replacements can be made as easily as possible. With Hotchkiss drive the front end of the rear spring is

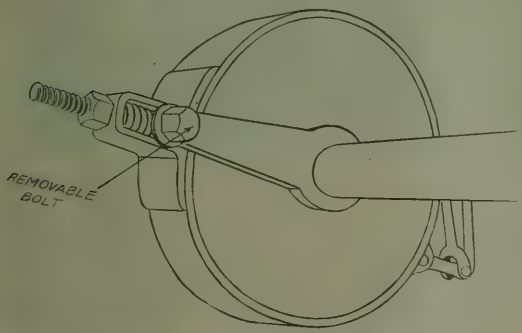


FIG. 11—REPLACING THE STUD ON THE BRAKE MOUNTING OR TORQUE-ARM WOULD MAKE IT POSSIBLE TO REMOVE AND REPLACE THE EXTERNAL BRAKE BANDS WITHOUT HAVING TO REMOVE THE REAR WHEEL

usually bracketed close to the under side of the frame channel. If the running-boards are dropped far enough below the lower edge of the frame, a hole can be provided in the running-board shield to make the forward eye-bolt of the rear spring accessible. Some cars were noted, however, in which this eye-bolt was almost if not quite in line with the running-board, making it difficult to get the eye-bolt out of the bracket. Of course the head of the bolt was toward the center of the car, but the nut on the outer end of the bolt was in a very confined space, and could be turned only with an open-end wrench.

In one or two cars the muffler location interfered with the removal of the forward rear-spring eye-bolt on one side. This could easily be avoided by moving the muffler forward a few inches.

In Figs. 12 and 13 an attempt has been made to illustrate how the various units can be disposed about the engine so as to make them all readily accessible, and in fact make the whole engine as accessible as possible for all service jobs likely to be required. Fig. 12 shows a

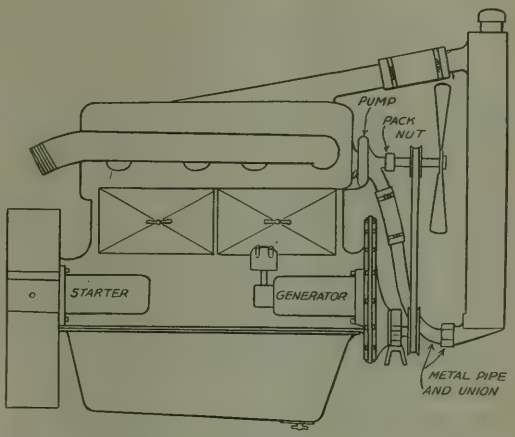


FIG. 12—AN EXAMPLE OF HOW THE VARIOUS UNITS CAN BE GROUPED ABOUT A TYPICAL THREE-POINT SUPPORT ENGINE TO PROVIDE THE MAXIMUM SERVICE ACCESSIBILITY

vertical engine with three-point support, the single point being at the front end, with the pump mounted on the forward end of the cylinder casting and driven by the fan-belt with a single packing nut on the pump shaft where it is readily accessible. With this construction, the fan-belt adjustment must be made by bringing two halves of the upper V-pulley more closely together, or providing an idler pulley at some other point. Note that the lower hose connection is made accessible by locating it immediately under the pump and using only a comparatively short length of rubber hose and below that a metal tube connected to the radiator outlet by a union nut. The generator and starting motor are both located on the right side of the engine with mountings similar to that shown in Fig. 9 on page 5. The carbureter is assumed to be on the left side of the engine, but could be located on the right side if desired. By mounting it fairly high and setting it out from the cylinder block somewhat, it would not interfere with the accessibility of the valve-adjustment mechanism. The oil-pump strainer cover and

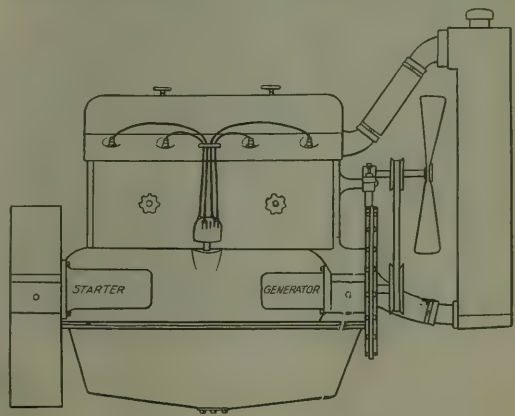


FIG. 13—ANOTHER TYPICAL EXAMPLE OF ACCESSIBLE GROUPING OF THE VARIOUS UNITS
This Engine Is of the Four-Point Support Type

crankcase drain-plug are shown at the forward end of the crankcase sump where they can be reached from the front of the car.

The engine in Fig. 13 is assumed to be supported at four points by two arms at the forward end of the crankcase and two supports on the flywheel housing. Fan adjustment is of the type illustrated in Fig. 1 on page 2. The generator and starting motor mountings are similar to that in Fig. 9 on page 5. Thermosyphon cooling is assumed, but if a water-pump is necessary, it could be located on the right side by moving the generator back under the igniter and locating the pump between the generator and the front-end drive, with sufficient space on either side of the pump to make the packing-nuts readily accessible. In this connection it should be borne in mind that the generator on the average car will in all probability have to be removed much more frequently than the water-pump; consequently it should be the more easily removable of the two.

Possibilities for Improvement in Current Models

It is realized that extensive changes in current models which are in regular production and in which no changes have been contemplated, would be expensive; nevertheless there are many little ways in which the service accessibility of many of these models could be vastly improved without involving heavy outlay. By changing one thing at a time, as the factory stock of various units is gradually used up, it would be possible to work in a number of little improvements which in the aggregate would make the cars much more accessible and would cost the factories very little. On the other hand, it is safe to say that every such improvement would more than pay for itself in a short time.

Any designing engineer who is deeply enough interested in this subject could make up a chart or table somewhat along the lines of the one discussed earlier in this paper, picking out any typical service operations, and rate his own car in comparison with others of the same price class or type of design and also with some higher or lower-priced and of radically different design. It is safe to say that in making such a comparison he will run across many little features which could be incorporated in his own car in one form or another, or which would suggest improvements to him. If such a survey could be made by a good service man with technical training, or by a consulting engineer, the results might be even better.

Factory engineers should give more attention to the design of special tools and equipment for dealers' service stations to facilitate service work on current models, and even on discontinued models if these are still in use in large numbers. The dealer's service manager is seldom capable of designing special tools and equipment for his own use, and even if he can design them, it is expensive to get them made in single units. The time is rapidly approaching when the factory engineering department will consider service station equipment for the cars they build, just as necessary as assembly equipment and machine tools for the factory. In this respect the ideal condition would be for the factory engineering department, when designing a new car, to design it for production accessibility and service accessibility, and design all necessary special tools and machine equipment for producing the various parts, the factory assembly equipment and all the necessary dealer service station tools and equipment, all before the car is actually put into production.

It is suggested that when a new model is being designed, or at least some time before the car is put into production, the distributors and dealers' service managers be called into conference, if at all possible, or at least some of them who have both technical training and service experience, and that they be asked to go over the new car and suggest improvements which would make it more accessible for service work. Undoubtedly a great many suggestions will be obtained in this way, which can be incorporated in the car design without great expense, if acted upon before final provisions have been made for production. The service man meets the public or in other words the car owners, and knows their needs and wants better than the factory or designing engineer can possibly know them. If it is impossible or undesirable to get the service managers together, or to consult them individually, it is suggested that the factory engineer make up a list of all important service operations, rated according to frequency or importance, analyze the preliminary design of the new car in connection with these service operations and see what improvements can be made to render the car as accessible as possible for all service jobs or at least the most important ones or those most frequently required.

Some factories have taken a step in the right direction by establishing a rule that the engineers responsible for the design of a new car shall drive the car for a considerable period during its development and do all work on it themselves. Undoubtedly much can be learned regarding service accessibility in this manner, but the important thing is that the lessons learned in this way shall be used in improving the design of the car and not forgotten or neglected as soon as the test trip is ended.

In designing new cars or models it is important that special attention be given to all the necessary service operations on closed cars and special body types. Closed cars are becoming more and more popular and must be made just as accessible for all service operations as the open models. All the standard body types, both open and closed, which are used on any chassis, should be taken into consideration so that the car will be 100 per cent accessible for service work, regardless of the type of body preferred by the purchaser.

Another minor point worth mentioning is consideration of the possibility of damage to various parts of the car in case of accidents or minor collisions which will sometimes occur, and to design the car so that the damage resulting therefrom shall be minimized as much as possible.

In conclusion, I desire to point out again that this paper is intended only as an opening wedge and to call attention to a few of the many ways in which improvements in service accessibility are possible. The subject is a vast one, and it is impossible to go into it very deeply in a short discussion, but it is hoped that this paper and the discussion to follow will open up some possibilities for further improvement in car design from the standpoint of service accessibility.

S. A. E. Summer Meeting

ARRANGEMENTS for the 1921 Semi-Annual Meeting of the Society have recently been completed and the Meetings Committee announces the selection of the West Baden Springs Hotel at West Baden, Ind., as the location for this year. May 24 to 28, inclusive, have been chosen as the meeting days, this period being about a month earlier than last year. West Baden was selected after a careful canvass of all of the places suited to the peculiar demands of a meeting of the size and character of that held by the Society. Since the Annual Meeting is always held in New York City, it is logical that a mid-western center should be chosen for the summer activities as in the past and it is desirable that the hotel appointments and grounds be of the best.

The beauty and unique character of the West Baden Springs Hotel cannot be exaggerated. The 520 rooms are arranged in a circle and the court in the center is covered, forming an immense room 200 ft. in diameter and 100 ft. in height, believed to be the largest room of this character in America, if not in the world. The hotel furnishings and equipment are in keeping with its unique architecture and equal to any found in our large city hotels. All of the rooms are large and comfortable and the majority have private baths connecting.

The facilities for recreation and the usual sports events could not be bettered. The golf course is situated on a large elevated plateau commanding a view of the entire surrounding country. The presence of numerous natural hazards results in a very sporty course and, in combination with carefully maintained greens, has made the course a favorite throughout the Middle West. There are tennis courts, a baseball diamond, swimming pool, and beautiful lawns where the customary sports program can be staged. Motion picture shows are given nightly in a special theatre; there are card and billiard rooms, bowling alleys and a swimming pool for indoor recreation; a stable of splendid horses is maintained for folks who ride. The surrounding country is exceptionally attractive and the general atmosphere of the spot is one of restfulness and health. The mineral waters at West Baden are well known for their medicinal value and every type of bath and treatment is provided. It is anticipated that very many of the members of the Society will prolong their stay at West Baden once they become acquainted with its charm.

The technical meetings can be conducted at West Baden under ideal conditions since there is a convention hall in the hotel which will be used as the principal meeting room. It is detached from the main lobby of the hotel and away from the noise and confusion which have been an annoyance at previous meetings. This room has a seating capacity of 750, has a high ceiling, and is constructed so that the view is nowhere obstructed by pillars. There are other excellent rooms available for meetings, and the plan of holding sessions simultaneously, which proved successful at the Annual Meeting in January, will be repeated. The program for the technical meetings has been outlined and indications point toward the presentation of papers that will be classed among the most noteworthy presented at Society meetings in the past. There will be sessions devoted to fuel, research, aeronautics, farm power, highways and transport and engineering relation to sales. The last subject is particularly pertinent at this time and should arouse unusual interest.

THE WEST BADEN SPRINGS HOTEL AT WEST BADEN, IND., WHERE THE 1921 SUMMER MEETING WILL BE HELD FROM MAY 24 TO 28

West Baden is 120 miles south of Indianapolis and it will be noted that the S. A. E. meeting closes on Saturday and Decoration Day falls on the Monday following. The members and their guests can arrange to attend the annual 500-Mile Race at Indianapolis on Decoration Day as part of their vacation because of this arrangement.

Negotiations are now being carried on with the railroads to secure the same reduced return-fare arrangement which undoubtedly influenced many members to attend the Annual Meeting in January. Special trains will be arranged from the principal automotive centers enabling the members to leave Monday evening, May 21, arriving in West Baden not later than the following noon. It is anticipated that many of the members and their guests will drive to West Baden and assurance is given them that proper garage facilities are provided at the hotel.

Compression Ratio and Thermal Efficiency of Airplane Engines

By Stanwood W. Sparrow[1]

Annual Meeting Paper *Illustrated with* Charts

IT is only recently that the old definition of an engineer as "one who can do with one dollar what any fool can do with two" could be applied appropriately to the aviation engineer. His task has been rather to do, at any cost, what "any fool" could not do at all and to

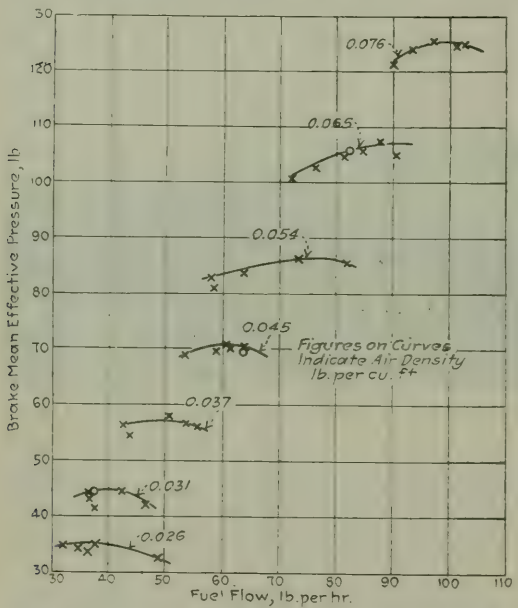


Fig. 1—Comparison of Brake Mean Effective Pressures Developed with Various Compression Ratios from the Same Amount of Fuel

his success the aeronautic achievements of the past year bear testimony. Now, however, it is assumed that the aviation engine will be reliable and of not unreasonable weight per horsepower, and the demand becomes one for higher efficiency or more miles per dollar. Foreseeing this demand and appreciating the fundamental relation of the compression ratio to the thermal efficiency, the National Advisory Committee for Aeronautics has sponsored a comprehensive investigation of this subject at the Bureau of Standards. Every effort has been made to measure the engine performance so completely as to make possible an analysis which will not only explain the results of this particular series of tests, but will also form a sound basis for predicting the effect of changes in the compression ratio on the thermal efficiency of any engine. Although not even the experimental work is entirely finished, it seems wise to present some of the more salient results at this time rather than withhold them for the more complete analysis.

For these tests an eight-cylinder airplane engine having a bore of 120 mm. (4.72 in.) and a stroke of 130 mm. (5.12 in.) was secured. Pistons were provided giving compression ratios of 5.3, 6.3, 7.3, and 8.3. These had all been run in in their respective cylinder blocks to insure a proper fit. The differences in the compression ratio were effected by crowning the piston-heads different amounts. The tests were made in the altitude chamber of the dynamometer laboratory in order that typical altitude conditions of air temperature and pressure might be obtained.

The tests which have been selected for consideration in this paper were made at full load with an engine speed of 1600 r.p.m. The temperature of the air entering the carbureter was in one case + 10 deg. cent. (50 deg. fahr.) and in the other — 10 deg. cent. (14 deg. fahr.). For each compression ratio the results were plotted in the manner shown in Fig. 1. This shows the brake mean effective pressure developed with different rates of fuel flow at altitudes from the ground to 30,000 ft. Although these curves show the effect of the air-fuel ratio on power, their real purpose was to make possible a comparison of the brake mean effective pressures developed with the various compression ratios from the same amount of fuel.

The air measurements showed that practically the same mass of air was taken per stroke with each compression ratio. Hence, the two curves of Fig. 2 apply to all of

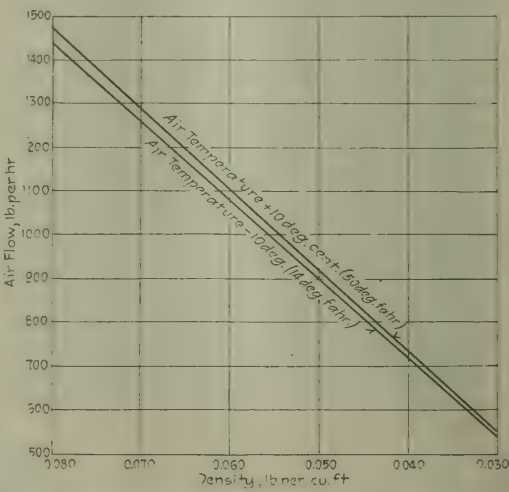


Fig. 2—Curves Showing the Relation Between Air Flow and Air Density at Different Temperatures

[1]M. S. A. E.—Mechanical engineer, automotive power plants section, Bureau of Standards, Washington.

the ratios used. The difference arising from the temperature change may cause some surprise. Since the results are plotted against air density or mass per unit volume, the increase in the quantity with an increase in the temperature obviously means a greater volume taken by the engine in a unit time. To discuss the reasons for this increase is beyond the scope of this paper. In passing, however, it may be pointed out that this answers a constantly recurring question; why, if the engine power is dependent upon the weight of charge received, does not a temperature increase cause a decrease in the power which is directly proportional to the resulting decrease in density? An inspection of Fig. 2 gives the answer that the volume of the charge taken by the engine increases with an increase in the temperature. The extent to which this volume increase offsets the density decrease determines the actual power drop.

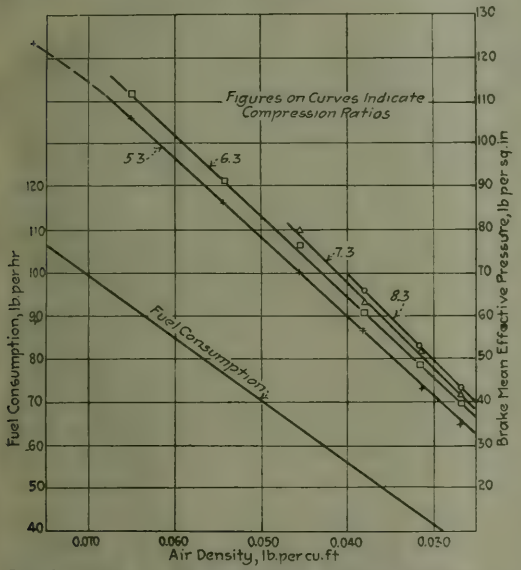


FIG. 3—CURVES OF THE BRAKE MEAN EFFECTIVE PRESSURE DEVELOPED WITH DIFFERENT COMPRESSION RATIOS AT A GIVEN RATE OF FUEL CONSUMPTION

For a comparison of engine performance on a basis of efficiency and power, the brake mean effective pressure developed with each compression ratio at a given rate of fuel consumption was plotted as shown in Fig. 3. These values were taken from curves of the type shown in Fig. 1, the rates of fuel consumption chosen being such as would be obtained with a carbureter supplying the same mixture ratio at all altitudes. Since Fig. 2 gives the air flow at all densities, it is merely a matter of division to determine the rate of fuel flow necessary to give any air-fuel ratio. It is of interest that the maximum power for these compression ratios at all altitudes was obtained with an air-fuel ratio of from 13 to 1 to 14 to 1. Fig. 3 itself needs little explanation. The lower curve gives the fuel consumption at any density, while the upper curves show the brake mean effective pressure developed from this amount of fuel with each ratio.

The absence of values for the higher compression ratios at the higher densities is due to the preignition that results under such conditions. The final temperature

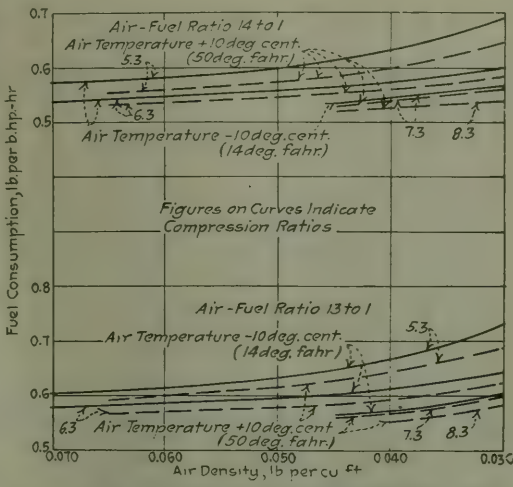


FIG. 4—CURVES OF FUEL CONSUMPTION FOR DIFFERENT AIR TEMPERATURES AND MIXTURE RATIOS

of a gas compressed adiabatically is given by the equation:

$$T_2 = T_1 r^{k-1}$$

where

T_2 = the absolute temperature at the end of compression
T_1 = the absolute temperature at the beginning of compression
r = the compression ratio
K = the ratio of the specific heat of the gas at constant pressure to that at constant volume

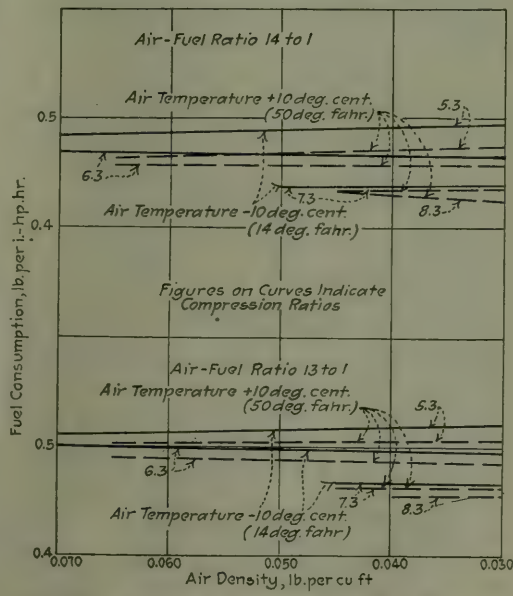


FIG. 5—FUEL CONSUMPTION IN POUNDS PER INDICATED HORSEPOWER AT DIFFERENT COMPRESSION AND AIR-FUEL RATIOS

TABLE 1—RELATION BETWEEN INDICATED THERMAL AND AIR STANDARD EFFICIENCIES

Compression Ratio	Air-Fuel Ratio	Temperature, deg. cent.	Temperature, deg. fahr.	Indicated Thermal Efficiency, per cent	Air Standard Efficiency, per cent	Indicated Thermal Efficiency in Terms of Air Standard Efficiency, per cent
5.3	13 to 1	+10	50	26.6	48.8	54.5
6.3	13 to 1	+10	50	27.5	52.2	52.6
7.3	13 to 1	+10	50	29.0	54.9	52.8
8.3	13 to 1	+10	50	29.5	57.1	51.8
5.3	14 to 1	+10	50	28.7	48.8	58.8
6.3	14 to 1	+10	50	29.4	52.2	56.3
7.3	14 to 1	+10	50	31.0	54.9	56.5
8.3	14 to 1	+10	50	31.5	57.1	55.2
5.3	13 to 1	—10	14	26.0	48.8	53.3
6.3	13 to 1	—10	14	27.0	52.2	51.7
7.3	13 to 1	—10	14	28.8	54.9	52.4
5.3	14 to 1	—10	14	27.6	48.8	56.5
6.3	14 to 1	—10	14	28.9	52.2	55.5
7.3	14 to 1	—10	14	30.6	54.9	55.8

The density of the charge does not appear explicitly in this equation. The key to its influence on the final temperature lies in its relation to the initial temperature T_1. This temperature depends upon the heat supplied to the entering charge by the hot walls of the combustion-chamber. The temperature of these walls and hence the amount of heat supplied by them is governed by the power developed. Since the power developed depends upon the density, the relation of the density to the temperature at the end of the compression is seen to be fundamental, although indirect. It must not be inferred that engine operation is impossible at these higher densities. Some fuels are known to give satisfactory operation under these conditions. The engine can be designed so as to render unnecessary development of full-load power at the lower altitudes. It seemed logical to determine first the gain that would result from increasing the compression and then to judge whether or not this gain would justify the change in fuel or the modifications in engine design necessary to employ such a ratio satisfactorily.

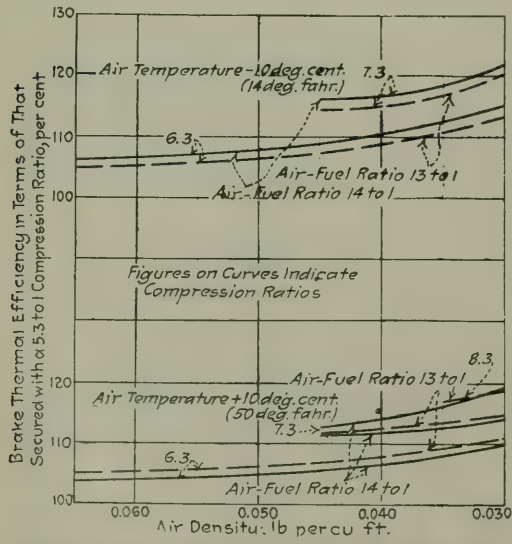


FIG. 6—BRAKE THERMAL EFFICIENCIES FOR DIFFERENT AIR TEMPERATURES AND COMPRESSION RATIOS OF 6.3 TO 1 AND 7.3 TO 1 EXPRESSED AS PERCENTAGES OF THE EFFICIENCY OBTAINED WITH A RATIO OF 5.3 TO 1

Fig. 4 summarizes the results showing the fuel consumption in pounds per brake horsepower hour for two air temperatures and two mixture ratios. The larger consumption at the greater altitudes is due to the higher percentage that the friction power there bears to the brake power. This is borne out by Fig. 5, where the fuel consumption is plotted in pounds per indicated horsepower hour. These curves suggest that the efficiency of combustion is influenced but little by a change in the density so long as the temperature is maintained constant. Temperature, on the other hand, appears to have a considerable effect. It is probable that an explanation of this will be furnished by a more complete analysis of these results. That the gain varies so greatly with the different compression ratios makes any explanation on the grounds of a change in distribution highly improbable.

As a matter of interest, average indicated thermal efficiencies and the corresponding air standard efficiencies have been tabulated and are given in Table 1. It will be recalled that the air standard efficiency for the Otto cycle is given by the expression

$$E = 1 - (1 \div r)^{k-1}$$

where

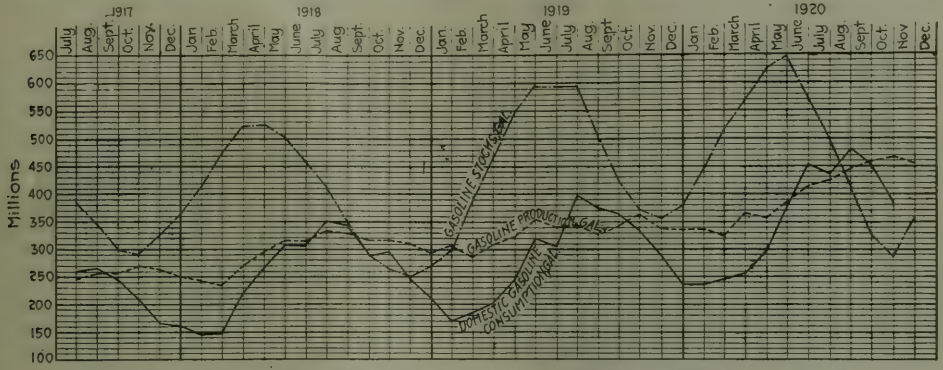
E = the air standard efficiency
r = the compression ratio
K = the specific heat at constant pressure divided by the specific heat at constant volume or 1.4 for air

Fig. 6 presents the brake thermal efficiencies as percentages of the efficiency of the 5.3 compression ratio. It brings out very clearly that the gain ensuing from the employment of the higher ratios increases with an increase in the altitude. This latter effect is due solely to the increase in power and the resulting smaller ratio of friction to brake power. Hence, the same condition would result from supercharging or from any other method of efficiently increasing the power developed. An example will illustrate the point. Assume a brake horsepower of 50, a friction horsepower of 20 and an indicated horsepower of 70. With a fuel consumption of 0.45 lb. per i.hp-hr. there would be used in 1 hr. 31.5 lb. This makes the consumption in pounds per brake horsepower hour 31.5 ÷ 50 or 0.63 lb. If the engine be furnished an increase in the charge weight sufficient for it to develop 80 i.hp. the fuel used will be 36 lb. per hr. Such an increase will not materially change the friction and the brake power will become 80 — 20 or 60 hp. The fuel consumption now becomes 36 ÷ 60 or 0.60 lb. per b.hp-hr.,

(*Concluded on page* 281)

Gasoline Production in November

THE production of gasoline for the month of November, 1920, according to refinery statistics compiled by H. F. Mason of the Bureau of Mines, shows a decrease of approximately 2½ per cent from the high point of October due in part to the difference in number of days in the two months. The quantity of gasoline produced by the refineries in the United States for November was 452,642,125 gal. as compared with 465,787,745 gal. in October, 1920, and this is at the daily rate of 15,088,071 gal., against 15,025,411 gal. for October, 1920, and 11,288,919 gal. for November, 1919. The production for the month of November is the third largest since statistics have been compiled, the two previous months alone surpassing the November production. On Nov. 30 the gasoline in storage at the refineries amounted to 354,835,764 gal., as compared with 301,283,731 gal. on Oct. 31, 1920, and 378,133,185 gal. on Nov. 30, 1919.

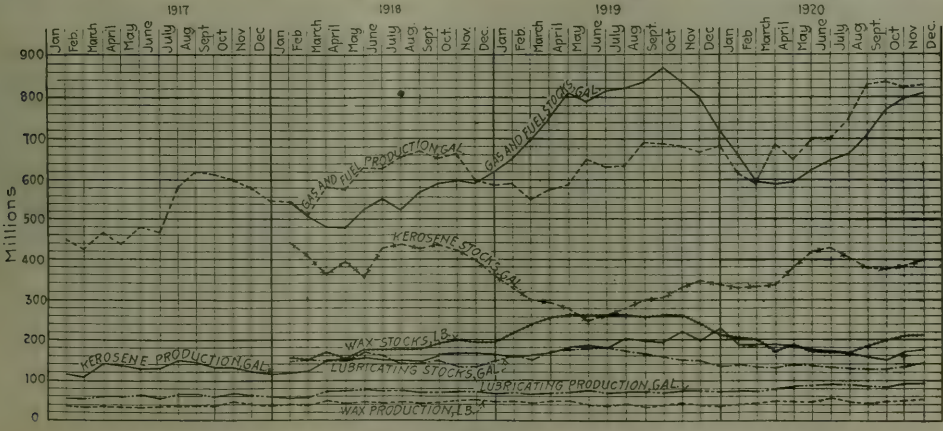


GASOLINE PRODUCTION AND STOCKS FROM AUG. 1, 1917, TO NOV. 30, 1920

All of the minor products of petroleum showed increases in the daily average production for November over that of October, although the total quantities show declines due to the fact that October was a 31-day month

PRODUCTION AND STOCKS ON HAND OF VARIOUS REFINERY PRODUCTS

	Production			Stocks on Hand		
Products	November, 1920	October, 1920	November, 1919	Nov. 30, 1920	Oct. 31, 1920	Nov. 30, 1919
Gasoline, gal.	452,642,125	465,787,745	338,667,570	354,835,764	301,283,731	378,133,185
Kerosene, gal.	214,804,177	213,742,156	214,829,910	398,991,592	383,828,239	347,070,560
Gas and Fuel Oil, gal.	822,638,305	823,114,603	663,309,510	808,802,516	799,024,084	791,052,991
Lubricating Oil, gal.	91,180,007	93,229,723	75,962,220	142,180,775	136,194,914	149,193,143
Wax, lb.	48,982,851	49,327,922	38,856,630	179,706,317	170,424,853	239,710,946



PRODUCTION AND STOCKS OF MINOR PETROLEUM PRODUCTS FROM FEB. 1, 1918, TO NOV. 30, 1920

while November had one day less. Kerosene, however, was an exception to this general rule, the total production for November amounting to 214,804,177 gal., as compared with 213,742,156 gal. in the preceding month. At the same time the stocks of kerosene increased from 383,828,239 gal. on Oct. 31 to 398,991,592 gal. on Nov. 30. The details of the production of the various petroleum products and the stocks on hand on Nov. 30 and Oct. 31, 1920, and Nov. 30, 1919, are given in the accompanying table and are shown graphically on a chart which is reproduced from the *National Petroleum News*.

In the month of November there were 326 refineries in operation with a daily capacity of 1,698,295 bbl. of crude oil, a decrease in the number of refineries of 6 and an increase in the daily capacity of 1350 bbl. as compared with the month of October. On Oct. 31, 1920, 332 refineries having a daily capacity of 1,686,945 bbl. of crude oil were in operation.

RESEARCH DEPARTMENT OF THE SOCIETY

THE establishment of the Research Department of the Society constitutes one of the most important steps that have been taken by the Society or on behalf of the automotive industry. It is fully as important as the original establishment of the Standards Department, and should obviously result in the dissemination of research data with as great benefit in an engineering way and industrially as has been consequent upon the promulgation and reduction to practice of the hundreds of S. A. E. mechanical and materials Standards. The Society has had for several years a Research Committee, which has applied itself assiduously to the clarification of methods of solving problems confronting the members, and the establishment of the Research Department is due to the work of the Research Committee and the view that it has expressed that it is essential that a well-equipped portion of the staff of the Society should devote its exclusive attention to supervisory and coordinative research work.

It is not the intention that the Society shall have a laboratory of its own or that any of its staff shall do directly research laboratory work. The program decided upon involves primarily coordination and elimination of duplication of work in various well-equipped laboratories, results from which, as well as facilities, will be available to the Society. It is becoming more and more clear to all how dependent the automotive industries are upon the work of the engineer. In turn, the engineer is wisely devoting himself more to the scientific application of his knowledge in the operation as well as of the design and production of apparatus of which the internal-combustion engine is the central factor. The problems in this connection are now international as well as national. With a number of laboratories pulling together, each will receive more of value than if it proceeded independently.

The Research Department is expected to act as a clearing-house for information and in a coordinating way on all research on subjects that are of immediate and pressing importance to the industry from time to time. Examples in this connection are factors entering into the design of radiators and fans, and proper gear tooth pressures for adequate length of life of gears in service.

The extent and province of the Research Department will be the supervision of work under the following general conditions: First, directing the work of such Government agencies as the Bureau of Standards and the Bureau of Mines in the determination of physical constants such as heat vaporization and calorific values of fuel, and to guide them in research work on general scientific engineering and industrial matters requiring standardization of elements of measurement in view of the needs of industry and commerce; second, supervising industrial laboratories in tests to settle engineering questions of immediate importance to industry; third, guiding the research efforts and programs of universities along scientific lines to definite commercial ends; fourth, gathering, indexing and digesting all available data on given subjects of dominating importance to the automotive industry, and fifth, through unity of plan and objective to eliminate duplication of research work in commercial laboratories, thus effecting vast economies.

It will be the function of the Research Committee to formulate the policies and to choose the specific researches to be undertaken, and to guide the Research Department to results of greatest industrial value. The Research Committee requests from the entire membership of the Society suggestions as to problems of great importance to the industry, and that all laboratories desiring to cooperate in the general movement be immediately placed at the disposal of the Research Committee for assignment on subjects which will be outlined later.

CRUDE RUBBER IMPORTS

ACCORDING to figures compiled by the Rubber Association of America, New York City, the importations of crude rubber into the United States for the year ended Dec. 31, 1920, amounted to 221,080 tons. These figures show a slight decrease from the imports for the year 1919, which were 231,511 tons. While February was the shortest month of the year the greatest amount of rubber was imported in that month, the figure being 32,994 tons. March ranked next with 31,650 tons and from then the imports gradually dropped, reaching the low figure of 6448 tons in November.

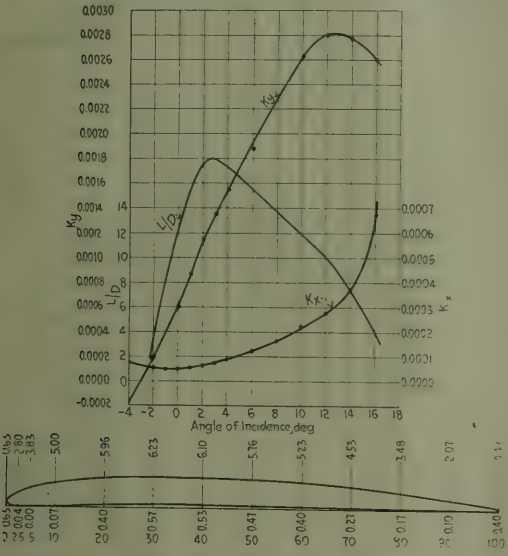
The 196,972 tons of Plantations grade constituted practically 89 per cent of the imports, while Para rubber ranked next with 18,391 tons or slightly more than 8¼ per cent of the total. Approximately 92 per cent of the Plantations rubber reached this country through the port of New York. A comparison of the figures for 1919 and 1920 shows that the African rubber was the only grade which was imported to a greater extent in 1920 than in 1919 and the increase there was only about 16 per cent. The imports of the Plantations grade were approximately the same in both years, while that of the Para rubber declined from 27,058 tons in 1919 to 18,391 tons in 1920.

Some Experiments on Thick Wings with Flaps

By C. D. Hanscom[1]

Annual Meeting Paper *Illustrated with* Charts

THE subject of thick wings has been taking on a constantly increasing importance in aeronautical discussions for several years. Since the war, with the urgent necessity for instant production removed, aeronautical engineers have been turning to practical

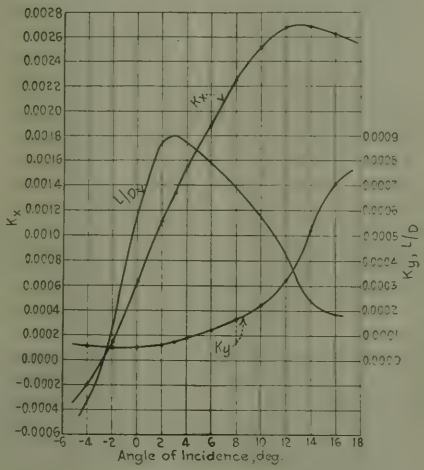


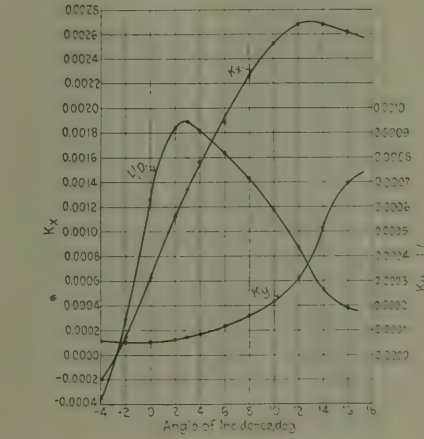
Kx, Ky and *L/D* Characteristic Curves and Section Ordinates for the D1 Wing Section

experiments. It should, therefore, aid in general aeronautic development if all information on the subject is made available for common use. The Glenn L. Martin Co. has recently had tests made in the wind tunnel of the Massachusetts Institute of Technology in the endeavor to obtain more data on the action of wings with flaps. Both front and rear flaps were employed, and the results showed several interesting features. When it was decided to have the experiments made, no sections were at hand which possessed all of the qualifications needed. It was especially desirable that the movement of the flaps should produce minimum discontinuities of surface. This requirement at once limited the choice of sections. Ultimately four base sections were adopted and the new wings developed from them.

Four Master Sections

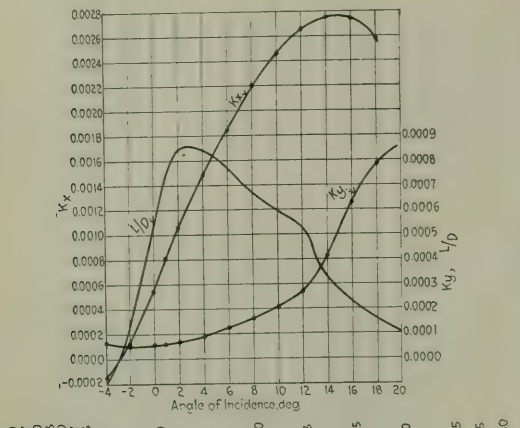
The first, and most logical, choice was the USA 27. The wing developed from this section eventually proved





Kx, Ky and *L/D* Characteristic Curves and Section Ordinates for the H1 Wing Section

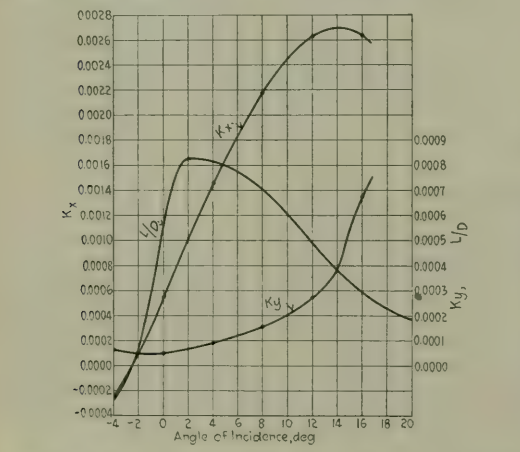
[1]Jun. S.A.E.—Chief engineer, Glenn L. Martin Co., Cleveland, Ohio.



Kx, Ky AND *L/D* CHARACTERISTIC CURVES AND SECTION ORDINATES FOR THE H3a WING SECTION

the best of those tried. The second base section was a wing of my own, the H1, the data for which has never heretofore been published. A third base section, which is now being shown for the first time by permission of its designer, G. M. Denkinger, was the D1. The fourth master section was a composite curve which resembled no wing in particular.

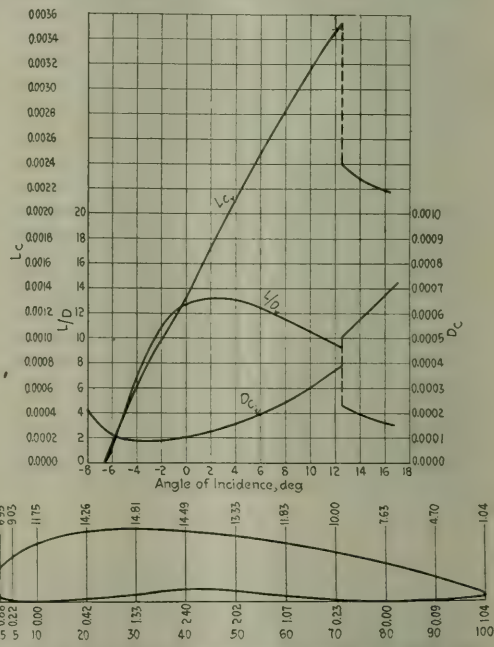
From these master curves, six new wings were designed. The USA 27 was thickened appreciably, and



Kx, Ky AND *L/D* CHARACTERISTIC CURVES AND SECTION ORDINATES FOR THE H3b WING SECTION

minor modifications were made in its form. The new section was called the No. 2. The D1 was uniformly increased in camber, by a percentage ratio, producing the Glenn Martin No. 5. The H1 was modified in three ways. The rear upper surface was raised in all cases to allow more room for the flap. This injured the qualities of the wing to a considerable degree. One wing designated as No. 1 was then made having a sharp trailing edge; another, No. 6, with a blunt trailing edge, and a third, No. 4, with a blunt trailing edge and a practically flat under camber. The fourth master section was modified only slightly, having been designed especially for the purpose. This latter was called No. 3.

The six models and the sockets were made at the Massachusetts Institute of Technology by its employes. The ordinates given in the different illustrations were scaled from sections of these models, and therefore represent to a good degree of accuracy the actual sections tested. The models were all 3 x 18 in., and the wind velocity was always 30 m.p.h. The tests themselves

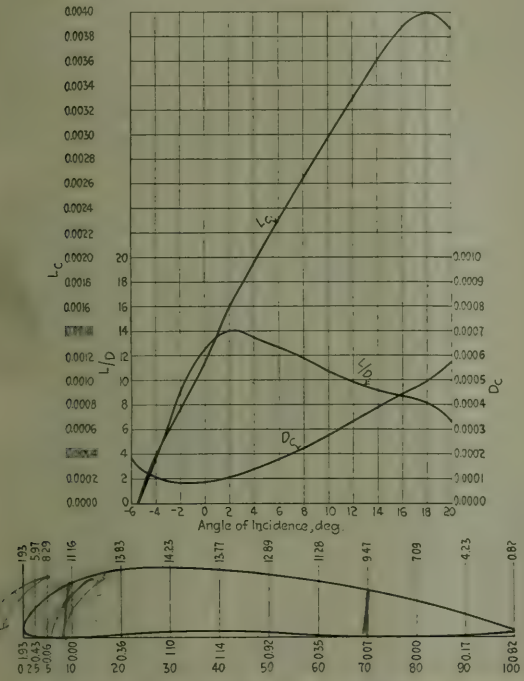


Dc, Lc AND *L/D* CHARACTERISTIC CURVES AND SECTION ORDINATES FOR THE GLENN MARTIN 1 WING SECTION

were under the personal direction of Prof. E. P. Warner. I was also present, and at the balance in most cases.

The special qualities which led to the selection of the four master sections deserve attention. The USA 27 was not thick enough, nor did it have a sufficiently high lift for the purpose of which it was needed. It was, however, by far the best thick section known. It was therefore only logical that it should be chosen. The form of the Glenn Martin No. 3 was arbitrarily adopted, the purpose being to combine low drag at small angles with good lift at higher angles. The *L/D* was better than for any of the other sections, but the lift proved unsatisfactory. The choice of the D1 and H1 wings was the result of private tests made in 1919. The D1 was de-

signed as a high-speed section. It actually proved to be one of the best known wings, of practical shape, at a lift coefficient of from 40 to 50 per cent of the maximum. In this range, and in fact everywhere above it, the D1 is much superior to the RAF 15. Below 36 per cent, at high speeds, it is inferior, although not greatly so. No change was made in the section in stepping all ordinates up by the same ratio to obtain the Glenn Martin No. 5. The H1 was designed to attain good efficiency at large angles, and if possible, a high lift. The high lift did not

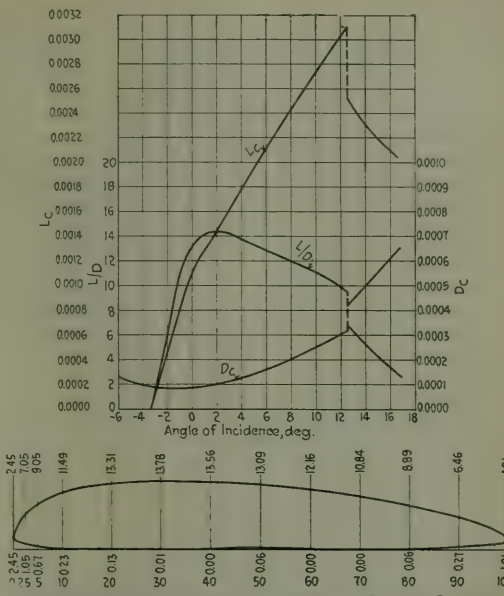


Dc, Lc AND *L/D* CHARACTERISTIC CURVES AND SECTION ORDINATES FOR THE GLENN MARTIN 2 WING SECTION

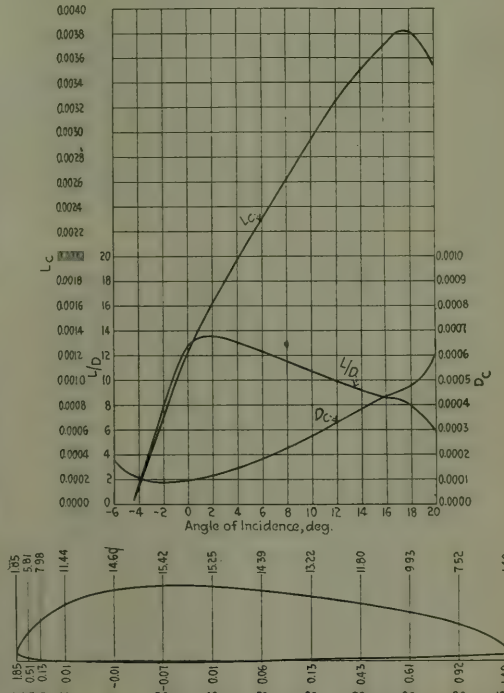
materialize, but the *L/D* at climbing speeds varying from 66.6 to 75 per cent of the maximum L_c is exceptionally good, being 16 to 15.[2] Two attempts were made to improve the lifting qualities of this section, by thickening the nose, but they failed to accomplish their object. The wings thus produced, H3a and H3b, are practically the same except that H3a has a very slight bump on the lower surface at 50 per cent of the chord. The difference in the characteristic curves is, therefore, noteworthy. H3a and H3b, however, merely indicated the advisability of making the modifications in H1 as small as possible.

Unfortunately, H1 had to be changed to a considerable degree to permit flaps to be employed. The rear lower surface had to be bulged down to accommodate the hinges and operating mechanism, and to relieve the sharpness of the break which would occur when the rear flap was

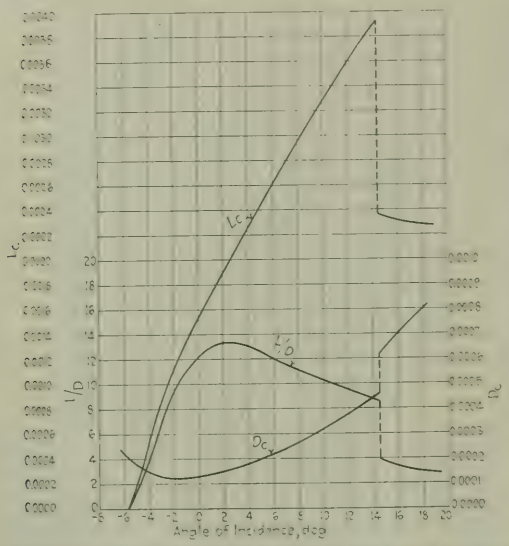
[2]Two sets of characteristic curves are shown for the H1. Those having the maximum *L/D* of 17.9 are the standard Massachusetts Institute of Technology tests. The others, with a maximum *L/D* of 18.9, show the same data corrected for spindle interference to permit of a direct comparison with the tests performed at the National Physical Laboratory, Teddington, England.



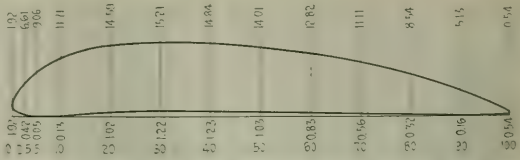
Dc, Lc AND *L/D* CHARACTERISTIC CURVES AND SECTION ORDINATES FOR THE GLENN MARTIN 3 WING SECTION



Dc, Lc AND *L/D* CHARACTERISTIC CURVES AND SECTION ORDINATES FOR THE GLENN MARTIN 4 WING SECTION



Dc, Lc AND *L/D* CHARACTERISTIC CURVES FOR THE GLENN MARTIN 5 WING SECTION

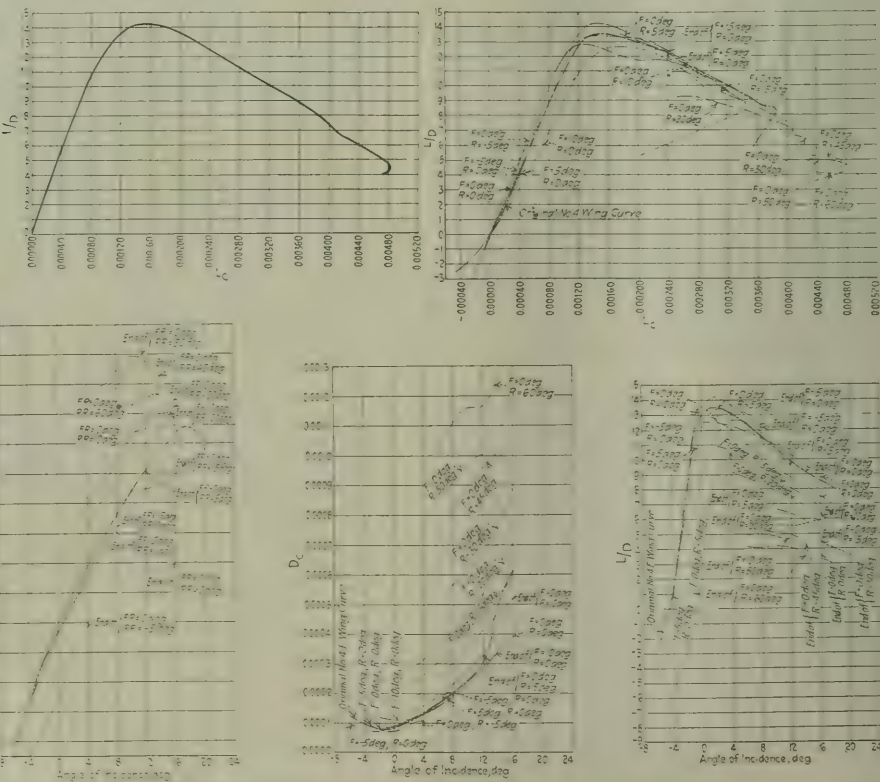


SECTION ORDINATES FOR THE GLENN MARTIN 5 WING SECTION

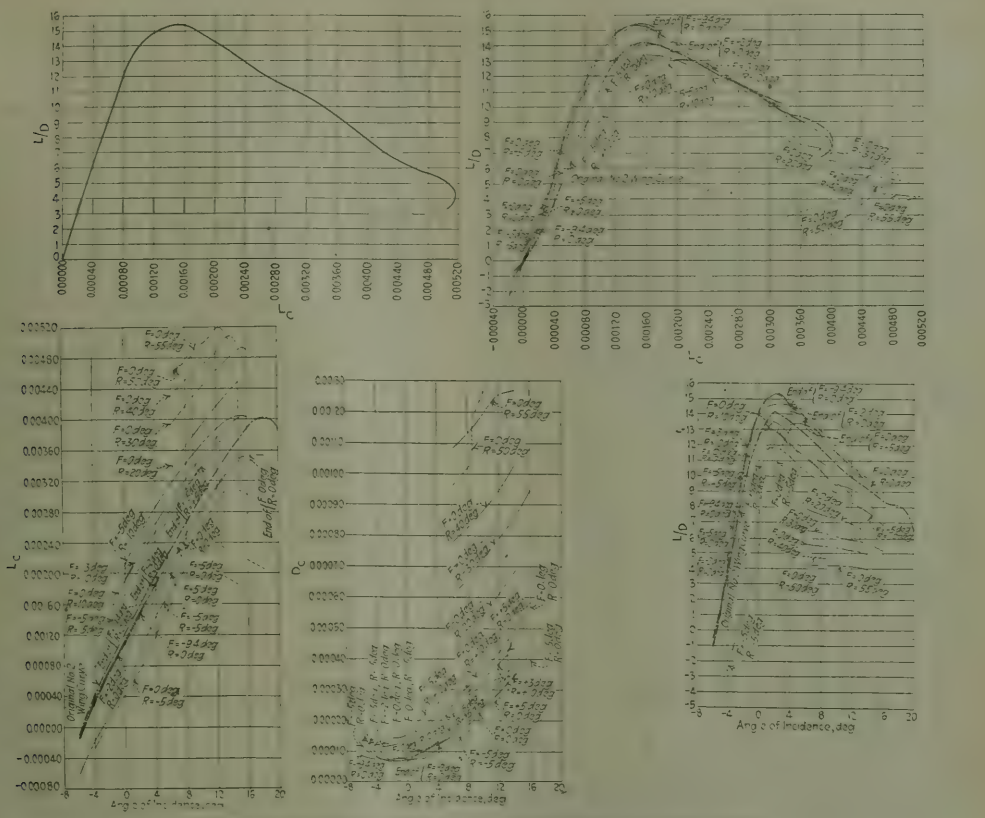
pulled down. These changes proved one point in the original design. Efficiency at high angles was obtained in the H1 by making the angles of trail, approximate angles made by the upper and lower rear surfaces to the chord, as nearly the same as possible. In other words, the trailing part was thin. The new Glenn Martin wings based on the H1 apparently lacked any exceptional efficiency at large angles because of the thickening of the trailing part out of proportion to the rest.

NEW WING DESIGNS

The six new wings are sufficiently described by the characteristic curves and tables of data. It may be noted that discontinuities occur in several cases at the burble point. This phenomenon is not unusual for thick wings, and, of course, disappears at higher velocities. It is obvious that the Glenn Martin No. 2 and the Glenn Martin No. 4 are the best of the six. The Glenn Martin No. 5



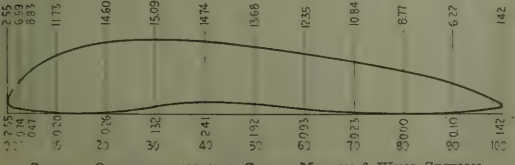
COMBINED CHARACTERISTIC CURVES OF THE GLENN MARTIN 4F WING SECTION



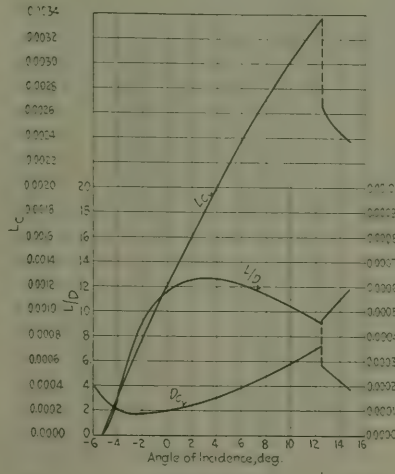
COMBINED CHARACTERISTIC CURVES OF THE GLENN MARTIN 2F WING SECTION

would undoubtedly have shown a higher lift in proportion as the velocity increased, but its lower efficiency ruled it out.

Sections Nos. 2 and 4 were therefore tested being hinged at 15 and 70 per cent of the chord length. The hinges were approximately 0.03 in. from the bottom surface, and the hinge-plates were sunk flush with the surface. The slight hollows at the hinge-plates and the cracks between the flaps and the main part of the wing were filled with plasticine. The sections were retested, and the errors of alignment noted. It is, of course, impossible to cut a wing in this manner and duplicate the original results, unless the model is metal. The errors, as indicated by a study of the model and the curves obtained, seemed due chiefly to lack of perfect alignment of the flaps. After a standard position for the flaps had



SECTION ORDINATES FOR THE GLENN MARTIN 6 WING SECTION



Dc, Lc AND *L/D* CHARACTERISTIC CURVES FOR THE GLENN MARTIN 6 WING SECTION

been determined, the other tests were run at accurate angles with respect to this standard; but the standard varied slightly from the original wing. Since the envelope curve is the ultimate goal, this minor error, while annoying, is relatively unimportant.

The Glenn Martin No. 4F, which was the No. 4 section with flaps added, was run first. The test demonstrated clearly that at very low angles of lift coefficient a negative angle is best for both front and rear flaps; but that at any speed ordinarily reached, the front flap only should be raised from the normal position. At high values of lift the front flap could profitably be in its normal position, and the rear flap should be down about 45 to 50 deg. It is only at the burble point and beyond that there is any noteworthy gain from the lowering of the rear flap.

The Glenn Martin No. 2F gave better results than the No. 4F, as expected. The conclusions drawn in regard to the use of flaps are almost identical. An angle of —5 deg. for the front flap is beneficial at all values of lift up to the burble point of the original wing. At very small lifts, the front flap can be raised even to —10 deg. with additional gain. In this latter region, also, the rear flap should be lifted to —5 deg. As the burble point is reached, the front flap apparently should come to 0 deg., and from there on the rear flap should be brought down by successive stages to about + 55 deg.

The qualities of the wings with flaps, as indicated by these tests, remain to be considered. The maximum lift increased 25 per cent for the No. 4F and 29 per cent for the No. 2F, over the original wing. These new maxima,[3] 0.00484 and 0.00516, constitute the highest lift coefficients yet attained as far as I am aware.[4] The drag at this extreme lift is, however, very high. It is interesting to note that for the No. 2F the L/D is 15.1 at 25 per cent of L_c maxima, and 8.4 at 11 per cent.[5] These values of L_c correspond to speeds of twice and three times the minimum respectively. It would therefore appear that for racing machines the use of a wing with flaps is highly desirable. For heavy weight-carrying planes, the drag would be high at low speeds; and the performance would resemble that of the Fokker-Junkers, which seems to be slow in pulling up from the ground, but climbs well when a good flying speed is attained.

The effect of an increase in speed and scale is uncertain, since experiments on thick wings with flaps have not been made. There is, however, no reason to believe that the wing characteristics would not improve to an appreciable extent. In any event, full-flight tests can soon settle the question.

[3] If a correction is applied for the reduction of chord and area with the flaps at large angles, L_c would approach 0.00575 in the case of the No. 2F.

[4] The largest value I have noted elsewhere is that recorded for the RAF 19 in Report and Memorandum No. 648, published by the Advisory Committee for Aeronautics (Great Britain). That report records $C_l = 0.93$, or $L_c = 0.00474$. The Handley Page apparently only reached $C_l = 0.8$, or $L_c = 0.00408$.

[5] The corresponding values for the RAF 15 obtained from National Physical Laboratory test are 14.5 and 7.7 per cent.

GASOLINE CONSUMPTION BY STATES IN 1920

THE American Petroleum Institute has compiled information showing the quantity of gasoline consumed in 1920 by 12 States which have oil inspection and where such information is available. In certain States all gasoline inspected is fuel gasoline, while in others it is impossible to estimate the proportion consumed by motor vehicles, except to indicate that the bulk of the gasoline consumed is for that purpose.

Without attempting to make any allowance for consumption by other agencies and without including in the compilation any estimate of consumption by motorcycles and motorboats, the figures shown indicate an average consumption of gasoline per vehicle, passenger cars and motor trucks, in the States where gasoline consumption figures are available of 452.1 gal. on the basis of the 1920 automobile registration figures. The total registration of passenger cars and motor trucks as of Dec. 31, 1920, was 8,887,572 cars, according to preliminary figures of *Automotive Industries*. On the basis of an average consumption of 452.1 gal. per vehicle, the indicated gasoline consumption by motor vehicles in 1920 was approximately 4,018,000,000 gal. The gasoline output of United States refineries in 1920 was about 4,870,000,000 gal.

In Arkansas all the gasoline inspected is fuel gasoline; therefore, the average consumption per car of 404.7 gal. is probably about correct. In Florida all gasoline inspected is fuel gasoline, but included in the total is the quantity consumed by motorboats. It is noted that the figures show Florida with a high rate of consumption. This figure may be influenced by the heavy use of cars by tourists.

No attempt at detailed analysis of the above figures is made, as it is recognized that there are several elements that might easily throw off calculations one way or the other. For instance, there is always difficulty in obtaining accurate registration figures. However, the figures obtained from the various States on gasoline consumption in 1920 constitute an actual record and make an unusually true basis for arriving at average gasoline consumption by motor vehicles. Estimates of the average annual consumption per car of motor vehicles in the United States have varied from 400 to 550 gal.

The following table gives the quantity of gasoline consumed in 1920, the number of cars registered and the average consumption per car for the States for which this information is available:

State	Gasoline Consumed, Gal.	Number of Vehicles	Average Consumption Per Vehicle, Gal.
Alabama	48,000,000	74,637	643.1
Arkasas	23,911,079	59,082	404.7
Colorado	51,452,244	128,951	399.0
Florida	53,735,278	57,000	942.7
Kansas	117,096,600	265,396	441.2
North Carolina	73,960,000	140,860	525.1
Ohio	273,411,650	616,800	443.3
Oklahoma	62,991,167	204,300	308.3
Oregon	44,900,669	103,790	432.6
South Carolina	41,225,067	92,818	444.1
South Dakota	41,000,000	122,000	336.1
Tennessee	57,841,190	101,852	567.9
Total	889,524,944	1,967,486	452.1

There is a decidedly different rate of consumption for passenger vehicles than for motor trucks. The average of 452.1 gal. obtained from the Institute's figures is inclusive of both passenger vehicles and motor trucks. Results from the experience of various fleet owners indicate that the average consumption of gasoline by motor trucks is about 1000 gal. annually, and the preliminary figures of the National Automobile Chamber of Commerce show approximately 900,000 motor trucks registered at the end of 1920. Accepting these estimates on the basis of the gasoline consumption figures shown above for the various States, the indicated annual consumption per passenger car is 390.3 gal.

Farm Power Meeting and Dinner

THE Sixth Annual Farm Power Meeting of the Society, held at Columbus, Ohio, on Feb. 10, during the week of the National Tractor Show, resulted in the presentation of much information of technical and economic value. More than 200 members and guests attended the professional sessions and the dinner. The various subjects discussed were of a very timely nature in this day of intensive study of agricultural, industrial and financial conditions from the National standpoint. The United States Department of Agriculture had just announced that the value of farm crops of 1920 and of farm animal products and animals sold and slaughtered was $19,856,000,000, this being $5,105,000,000 less than the corresponding figure for 1919. Despite the drop in prices the total value of farm products for last year was about 100 per cent greater than it was in 1914, which was a record breaking year; the value of the 1920 crops was more than 80 per cent greater than that of 1914 or 1913, 1913 having been a banner year. The Department of Agriculture estimates that the value of all crops in the United States was 2 per cent higher in 1920 than the average value of the 5 war-years. In this connection it is understood that the farmers of this country own 2,500,000 passenger cars and motor trucks, and that 60 per cent of the automobiles produced last year were purchased in agricultural districts. In emphasizing the fact that the American farmer cannot get along without those tools that are necessary for efficient production in his field of endeavor, L. J. Taber, master of the Ohio State Grange, stated that, whereas the American farmer purchases 45 per cent of the manufacturing output of this country not exported, his dollar has decreased in relative value recently 56 per cent.

Plowing Speeds

E. A. Johnston, the vice-president of the Society representing tractor engineering, presided at the technical sessions. D. L. Arnold, chairman of the Society committee that has been making an exhaustive study of plowing speeds reported on its current work. He made it clear that less power is required to plow with three bottoms than with two bottoms at the higher speed necessary to cover the same acreage in a given time; furthermore that at the same speed the cost of the three-bottom plowing is less. The power required increases with the speed, apparently regardless of the type of soil, that is, in about the same proportion in sand, stubble or 7-year old sod. The cost becomes less as the speed increases, and about proportionally with all soils. Mr. Arnold feels that while certain fundamental facts with regard to plowing speeds have been determined definitely, much further research is necessary in connection with them. He advocates the use of the term "rate of plowing" or "plowing velocity" in expressing plowing speed, inasmuch as with changing conditions high speed of today may be considered low speed tomorrow. Professor Davidson, of Iowa State College, confirmed the general deductions made by Mr. Arnold, stating that the variation in the depth of plowing has more influence than speed on the amount of power required. He said that about 14 factors are involved in determining the draft of a plow, the principal increase in draft being due to the effort necessary to turn the furrow slice. He expressed the opinion that the shape of the moldboard does not affect the draft and that there is an opportunity to change the design of plows so that they will have less surface in contact with the soil.

Chairman Johnston said that the draft of a 14 in. plow varies from 200 to 1800 lb., and that, as there is no one best plowing speed for all conditions, it will be necessary to standardize on perhaps three different speeds. Major O. B. Zimmerman said that the committee's experiments are of vital importance as it is essential to secure economic gain, however slight this may be, by the institution of scientific methods in farm-power operations. Every detail should be gone into carefully with a view to attaining the best possible results with a tractor having an assumed life of 7 years. Granting that the cost of the tests being made will amount to $50,000, the work will nevertheless result in a net saving in comparison with determining the right plowing speeds by empirical methods.

Tractor Belt Work

John Mainland, chairman of the Committee on Pulley Widths and Speeds, mentioned the 5, 6, 7, 8 and 9 in. belt widths which had been recommended for standard at the last meeting of the Standards Committee of the Society, no recommendations as to standard lengths being made. The current recommendations would if accepted result in a modification of the present pulley and belt width standards by replacing the 4 in. belt width with 5 in. and adding the 9 in. It is felt that a 4 in. belt is not practical for tractors from the driven-machine standpoint. According to the recommendation of the committee, the pulley is to be at least ½ in. wider than the belt to be used on it.

Mr. Mainland is convinced that all tractor engines should be equipped with governors, as these are necessary in operating belt-driven machinery with tractors and it is advisable to use tractors in as many farm operations as possible.

Authoritative data on belt and pulley speeds employed in farm work in this country are scarce and the committee has a strenuous task ahead of it to secure and collate an adequate amount of such data. All economic losses, such as belt slippage, must be reduced to the lowest possible minimum.

Anti-Freezing Solutions

The subject of anti-freezing solutions, which is of yearly recurring interest, is of such importance in the tractor field that a special committee of the Society was established for the purpose of making a thorough study of the use of certain mineral oils and of mixtures of salts or fluid chemicals with water to lower the freezing point of the mixture, with a view to making specific recommendations of constructive value in the operation of tractors. Major Zimmerman, who is chairman of this committee, made a progress report at the Columbus meeting. He said that it may be necessary for the committee to undertake research in a way analogous to that followed in the case of lubricants and fuels. Disregarding the mineral oils, the cooling medium should be cheap and easily obtainable, non-corrosive, not cause electrolytic action, have a boiling point not too high above that of water, not freeze much above — 20 deg. fahr., have low viscosity, be a minimum fire hazard, have high thermal conductivity and

possess other characteristics which Major Zimmerman enumerated. Concerning the use of salts like calcium chloride, it is stated that the hope that the average user would make his own solution is futile. The committee feels that the use of salts for preventing freezing is undesirable in view of the almost certain electrolytic action involved therein. The free boiling off of alcohol means uncertainty as to the nature of the solution in the engine. However, a mixture of 1 part amyl alcohol to 39 parts of water freezes at — 20 deg. fahr., and unlike ethyl and methyl alcohol has a boiling point of 264 deg. fahr. Its intoxicating effect far exceeds that of ethyl alcohol. With regard to the group of mineral oils, the committee feels that the arguments against these for use as anti-freeze fluid are based in large part on lack of accurate information. Tractors have been cooled successfully for many years with heavy oils during all seasons. The committee will endeavor to secure complete technical data on the characteristics of the mineral oils in question.

John A. Secor, pioneer engineer of the Advance-Rumely Co., said that his company had used oil for cooling for 12 years and equipped 30,000 tractors with oil-cooling means adapted to all climates and atmospheric temperatures. The packing in the pump gland requires replacement usually about once each season. The cooling oil is circulated by a centrifugal pump driven from the engine camshaft. Ordinary commercial Winter Black oil is used. The oil should be non-freezing and have an initial boiling point of not less than 500 deg. fahr. Radiators designed for water cooling are not ordinarily suitable for oil cooling. The general characteristics of Winter Black are as follows:

Pour Test, deg. fahr.	20
Viscosity at 104 deg. fahr., sec.	181
Viscosity at 210 deg. fahr., sec.	46½
Flash Point, deg. fahr.	345
Fire Point, deg. fahr.	385
Range of Boiling Points, deg. fahr.	550 to 750

On account of the viscosity of the oil at freezing temperature, it is customary to add kerosene to the Winter Black in the winter for adequate pumping action. As warm weather approaches, the kerosene evaporates gradually. The average temperature of the cooling oil as discharged from the cylinder jackets is from 175 to 200 deg. fahr. Winter Black does not deposit tarry material at its working temperatures. Mr. Secor made it plain that only suitable oil of known characteristics should be used for cooling. Engine lubricating oil is not suitable.

Dr. D. R. Harper gave an outline of the research work on radiators that has been done at the Bureau of Standards. He said that while the scientific work that has been done here and abroad provides much information, there are few data suitable for use in preparing specifications for radiators for automobiles and tractors, although under known conditions some of the results obtained in testing aircraft radiators are applicable. The heat transfer varies as the 0.8 power of the air-flow, the flow of air through the radiator being less than the velocity of the radiator through the air. It is necessary to know the actual rate of air-flow through the radiator core. The matter of the course of travel of air after it passes through the radiator has received too little attention. The specific heat of the cooling medium is of course important, but its thermal conductivity is so great that there is practically no difference in the temperature of the liquid and of the metal with which it is in contact. The Bureau of Standards has done only preliminary work in the study of anti-freeze solutions. Dr. Harper said that ordinary ethyl alcohol has a corrosive effect on copper and brass.

Nebraska Tractor Tests

Prof. Oscar W. Sjogren gave an exposition of the tractor tests conducted and the equipment used in furtherance of the provisions of the law of the State of Nebraska regarding the sale of tractors there. His presentation of the subject was clear and comprehensive and very closely followed. The law mentioned provides in substance that tractors sold in Nebraska shall be tested and passed upon by a board of three engineers under State University management, that those selling tractors shall secure from the State Railway Commission a permit that is issuable after the respective stock models of tractor have been tested as aforesaid. The official test includes a 12-hr. limbering up run, a brake-horsepower test at rated load and speed for 2 hr., a brake-horsepower test for 1 hr. at various loads to show fuel consumption under variable load and speed control of the governor, a brake-horsepower test at maximum load for 1 hr., a brake-horsepower test at one-half load for 1 hr., a drawbar horsepower test at rated load for 10 continuous hr., a maximum drawbar-horsepower test, and an investigation of the turning radius, the effectiveness of the brakes and of other apparently important features. The length of the test varies from 28 to 58 hr. The general nature of the testing equipment was described by L. W. Chase at the 1920 Annual Chicago Meeting of the Society.[1]

With regard to weaknesses developed in the tractors by the runs, Professor Sjogren said that some of the changes made during the tests were due to a lack of knowledge on the part of the operators, but that in some cases defects had been overlooked at the factory. He believes that exhaustive factory tests of tractors should be made by a corps of men having no part in the design work. Most of the trouble encountered in the cooling systems was due to the fan belts, although some cylinder-head water-passages were too small. In a few instances a change of carbureters resulted in increase of power output. Professor Sjogren is of the opinion that close control of injected water is necessary; also that there is a conspicuous need for further development of air-cleaners. Some of the governors installed were very ineffective.

Pulleys of the detachable type gave trouble, due to the short shaft mounting, with only one bearing usually. Some pulleys were mounted in such a way that the belt dragged on the steering-knuckles of the front wheels. In other cases it was impossible to line the engine up in a short time.

Of the 68 machines which appeared for test 39 went through without making any changes, while 29 made changes as follows: 11 failed to make their original rating, 7 of these have changed their ratings; 6 changed their rated engine speed; 11 changed some item of equipment; and 3 withdrew after the preliminary test.

Professor Sjogren advocates the rating of tractors according to a standard. Of the 60 tractors which completed the test, 51 had a manufacturer's rating for belt horsepower in excess of the rating that was formerly a standard of the Society, namely, 80 per cent of the horsepower that the engine is guaranteed to deliver at the pulley continuously for 2 hr., the engine being in good condition and properly operated at its rated speed. Of the tractors tested only four failed to develop as much belt horsepower as was specified in the respective manufacturer's rating.

[1] See THE JOURNAL, January, 1920, p. 44.

With reference to drawbar horsepower, 44 of the 60 tractors were rated in conformity with the former S.A.E. Standard for tractor drawbar horsepower, namely, 80 per cent of the horsepower that the tractor is guaranteed to develop at the drawbar continuously for 2 hr., the tractor being in good condition and properly operated at the rated engine speed, and on ground sufficiently firm to give the traction wheels a good footing. Two tractors did not develop as much horsepower at the drawbar as the manufacturer's rating specified.

The former S.A.E. Standards mentioned above were cancelled last year upon recommendation of the Tractor Division at the meeting of the Society held in June. There had been considerable adverse criticism of the drawbar-horsepower-rating standard, on account particularly of the belief that in regular procedure it is not feasible to make tests "on ground sufficiently firm to give the traction wheels a good footing, firm sod being preferable," as set forth in the former standard. It was argued that the basis of tractor rating should be the engine displacement, and the Tractor Division made in June 1919 a specific recommendation to this effect, which was not accepted by the Standards Committee. The tractor horsepower formula developed by the 1919 Tractor Division, this being based on engine displacement as stated, is considered a commercial rather than an engineering formula. An extended discussion of the whole matter was reported in THE JOURNAL[2] and as a matter of general information the displacement formula was included in the old Vol. I of the S.A.E. HANDBOOK, page 20b, together with data relating thereto. This matter is not contained in the revised Vol. I of the Handbook recently issued, for the reason that it is intended generally speaking that henceforth this volume shall include only S.A.E. Standards and Recommended Practices.

Professor Sjogren said that in the tests the consumption per brake-horsepower-hour was about the same with kerosene as with gasoline, and that the greater crankcase oil dilution consequent upon the use of kerosene did not make the cost of the use of kerosene as much as that of gasoline. He felt that it was superfluous to mention that it is inadvisable to use kerosene in a gasoline engine.

In the discussion of wheel lugs, Major Zimmerman said that these probably constitute the weakest point in the knowledge of tractor design today; that while a plow should be designed to give the maximum disturbance of the soil with a minimum expenditure of energy, the opposite is true in the case of the tractor, this making the matter of wheel design very important. Professor Magruder said that a special study should be made of power transmission losses. The amount of power lost between the engine shaft and the drawbar sometimes amounts to many times what is gained by increased fuel economy.

CARBURETION OF ALCOHOL

A. W. Scarratt made a valuable contribution in the form of a report on intensive experimental work done recently by the Minneapolis Steel & Machinery Co., with which he is associated, in developing an engine to burn alcohol economically and efficiently. Pointing to the increasing demand from abroad for American farm power equipment, he said that the greatest obstacle confronting tractors exported from this country is the use in an economical and satisfactory manner of fuels available in foreign countries. In Cuba, Brazil, Argentina, Chile, Porto Rico and Venezuela petroleum fuels are very expensive, while alcohol is comparatively cheap. The types of gasoline engine usually produced in this country for installation in tractors will operate on alcohol but in an inefficient manner.

It is difficult to vaporize alcohol; it ignites at a considerably higher temperature than gasoline, is only six-tenths as rich in heat units as gasoline by weight and is 15 to 20 per cent heavier by volume. Commercial alcohol contains approximately 10 per cent of water by weight. Its range of distillation temperature is from 158 to 175 deg. fahr. Mr. Scarratt said that more heat has to be applied to alcohol than to kerosene mixtures for good operation. In his experiments two types of carbureting and manifold methods were used, one a special Twin-City Holley system, and the other the Twin-City vaporizer previously described in THE JOURNAL.[3] The brake-horsepower developed with alcohol was more than equal to that ordinarily developed with gasoline or kerosene for the same expenditure in British thermal units. A compression of 110 lb. gage was finally settled upon as giving the most satisfactory results. The engine used was a 16-valve four-cylinder 4 x 6-in. Engine starting is somewhat more difficult when using alcohol, on account of the greater cranking effort necessary and the fact that air at ordinary temperatures does not vaporize the alcohol sufficiently to make a good combustible mixture. Satisfactory starting was accomplished by redesigning the starting-crank and using a 4-to-1 mixture of alcohol and gasoline.

Mr. Scarratt said that very generous provision for heating the alcohol fuel charge must be made, he having found that utilization of the entire exhaust heat was necessary. In addition to heating the alcohol, the air was heated to 210 deg. fahr. The temperature of the ingoing charge, for good carburetion and economical operation, should not be less than 100 deg. fahr. Good distribution of the mixture to the cylinders is essential when using alcohol at high compression. The intake-manifold gas velocity, at full load, should not be less than 9500 ft. per min. average.

The fact that alcohol vaporizes at a practically constant temperature is of marked advantage in engine operation, once the engine is properly warmed-up. Mr. Scarratt found practically no carbon residue resulting from the use of alcohol; the valve-seats were in surprisingly good condition after long hard runs. No pre-ignition was experienced. He believes that if the automotive industry demands the manufacture of alcohol for fuel purposes, it will head the list of automotive fuels eventually.

Mr. Secor said that in some parts of the world alcohol is the cheapest engine fuel available; that it had been reported that tractor engines are operated in Esthonia on alcohol at a rate of consumption of 0.735 lb. per hp-hr. with 85-lb. gage compression. Mr. Johnston said that while it is feasible to secure a thermal efficiency of 0.65 lb. per hp-hr. with kerosene and of 0.53 with gasoline, there is room for much improvement in fuel economy under average operating conditions.

TREND OF TRACTOR DESIGN

Mr. Johnston gave some very illuminating information by showing some moving pictures of an experimental two-plow tractor designed for use with many kinds of farm operating equipment, the various implements being readily attachable and detachable without the use of tools of any kind, such as hand socket-wrenches. It appeared that the development which Mr. Johnston demonstrated

[2] See THE JOURNAL, August, 1919, p. 188.
[3] See THE JOURNAL, August, 1920, p. 123.

was a revelation of tremendous importance to the tractor industry, agriculture and the Nation. The essential feature of the apparatus is the transmission of the power directly from the engine to the implement, eliminating the transmission of power through a ground wheel. This, Mr. Johnston said, causes less trouble in operation and has other advantages.

Mr. Johnston stated that the tractor will succeed in the degree that it is made profitable to those using it, and that the whole matter is a question of tractor design. With regard to the relative merits of wheeled and track-laying tractors, he is of the opinion that each of the types is satisfactory in its field. The two great essentials of the tractor are reliability and economy. The operator cannot be expected to make many, if any, adjustments; a minimum of attention must be required. The stresses to which such elements as gears and sprockets are subjected should be low enough to assure long life. A high-grade product is requisite.

As an elementary principle, tractors should be equipped with a power-takeoff. On most farms many of the extensively diversified operations are of such a nature that power cannot be applied to them with heavy tractors. The production per man must be increased. This problem is of an engineering nature and is solvable by the proper application of automotive power.

The cultivator equipment that Mr. Johnston showed will cost and weigh, he said, 75 per cent as much as a horse-drawn cultivator. He exhibited a 14-ft. cut mower which weighed about the same as a 6 or 7-ft. cut horse-drawn mower. It is estimated that with the tractor equipment one operator can mow hay at the rate of 4 acres per hr. The 12 to 14-ft. hay raker should increase the capacity per man 300 to 400 per cent. Another implement shown gathers and carries 8 to 12 shocks, this constituting a sufficient capacity to keep a small separator supplied, equalling the work accomplished by three teams and six men. Hay or other material such as cornstalks which are difficult to handle by hand are lifted by derrick. The 10-ft. binder and harvester can be produced, it is said, at 60 per cent of the cost of a horse-drawn harvester. Another of the apparatus is a 10-ft. binder with automatic shocker. The 14-ft. header weighs and costs half as much as the corresponding horse-drawn implement, and the field can be opened up without tracking down the grain. The husking is done in the field. A two-row snapper, picking ears from stalks without husking them, was shown. There is also auxiliary apparatus for doing spraying or for pumping water in case of fire, direct from the engine.

The principle upon which Mr. Johnston has proceeded is that it is possible to design a machine that will replace on a farm of from 100 to 150 acres all the seven to nine horses usually employed thereon. The main fact to be kept in mind is that each horse itself consumes the product of five acres. It is estimated that the cost of operation of the power equipment is 60 per cent of that of the horse-drawn. While there is no doubt, Mr. Johnston said, that the tractor for heavy belt and drawbar work, which is being developed rapidly, is profitable, some such power equipment as that he showed must be produced for use on small farms, that is those of 50 acres or less.

In connection with electric lighting and starting for tractors, Mr. Johnston confirmed the opinion that there is always a demand for such conveniences. He feels, however, that most designers do not favor the installation of electric starting apparatus on tractors now, in view of the doubt as to the ability of storage batteries to withstand satisfactorily tractor operating conditions. Considerable night work is done with tractors on the Pacific coast, lighting being had with acetylene as a source or from constant-voltage generators without a battery. In some instances tractors are operated continuously for 22 hr. for six days of the week.

Dinner Addresses

Professor Davidson presented the view, contrary to those ordinarily expressed, that there are now a sufficient number of men resident on farms in this country, and that the main things to be borne in mind are increasing the production efficiency per man and the comforts, conveniences and attractions on farms. There are 8000 less farms in Iowa than there were 10 years ago. In India 90 per cent of the population live on farms. But this is not evidence of a healthy condition, the standard of agriculture being of course low.

Professor Davidson said that he had been reliably informed that there are millions of acres of unused land in China, and averred that what is needed is efficient agriculture. The strength of a country depends upon the status of its rural life. The country has always replenished the cities. A high capacity for production means a high standard of the individual. It is possible now for one man to produce 30 times as much in the way of farm product as he could produce in 1830. Twenty-five to thirty million horsepower is used in various forms in agriculture. Included in the equipment on the farms in this country are 42 per cent of the buildings of the Nation. We have 200,000,000 acres of unused cutover land available. For the purpose of comparison, Professor Davidson pointed to the fact that there are 35,000,000 acres of land in Iowa. He said that 80,000,000 acres are reclaimable by draining, and 150,000,000 more by irrigation. With regard to fertility, he said, in connection with agriculture being one of the largest fields for engineering, that the soil of the Eastern portion of the United States can if necessary be brought back by known methods to a state of real productivity. The average farm practice in this country is not anywhere near the best that is feasible. Farm engineering has developed on a probational basis, the farmer not having been able to pay the engineer adequate fees. Capacity farming means of course capacity buying by the farmer.

Mr. Taber, master of the Ohio State Grange, said that the automotive engineers can do more for civilization than any other body of men of equal number in this country. The progress in agriculture that has been attained is the result of the work of the automotive engineer. Manufacturing genius developed America. Power generation and farm machinery are inextricably interwoven.

Speaking on behalf of over 100,000 Ohio farmers, Mr. Taber said that there is no "non-partisan" radicalism, socialism or communism among them. The farmer is loyal and will not be radical unless the financial-manufacturing interests are blind to rural conditions. The farmer is not on a strike but awaiting the economic adjustment that is necessary. He cannot be forced to buy, but he cannot do without the things that are essential for efficient production. A better understanding between the people of the country and of the towns is requisite. By cooperation between the engineer and the farmer on grounds of fair agreement, great progress can be made.

(*Concluded on page* 287)

S. A. E. Exhibit at the Columbus Tractor Show

THE cut-away engine shown in the foreground demonstrated the reduction to practice of many of the more than 40 S.A.E. Standards established for use in the design and construction of automotive engines of the internal-combustion type. Of the more than 200 S.A.E. Standards and Recommended Practices a larger number are applicable in the fabrication and installation of engines than in any other assembly unit of motor vehicles. Nearly 100 of the S.A.E. Standards are suitable for use in the design and construction of tractors and many of these are being applied in this connection more and more widely.

SOCIETY EXHIBIT AT THE SIXTH ANNUAL NATIONAL TRACTOR SHOW ILLUSTRATING THE EMPLOYMENT OF S.A.E. STANDARDS IN THE CONSTRUCTION OF AN INTERNAL-COMBUSTION ENGINE

COMPRESSION RATIO AND THERMAL EFFICIENCY OF AIRPLANE ENGINES

(*Concluded from page* 268)

a 5 per cent decrease. With a supercharger furnishing the increased charge, the efficiency of the supercharging device would enter the calculation making the net gain less. If, on the other hand, the increased power were obtained by an increase in the compression ratio, the gain would be more because there would be a lower fuel consumption in pounds per indicated horsepower hour with the higher ratio. In other words, with an increase in the compression ratio there is a gain in the indicated efficiency that is peculiar to this method of increasing power and, in addition, a gain in the brake efficiency that is common to all methods of increasing power.

Intake Flow in Manifolds and Cylinders

By P. S. Tice[1]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS

SEVERAL months ago, in the execution of a certain piece of work, it became evident that the air flows in the passages generally employed were not nearly so simple and orderly as our small knowledge of such matters had led us to expect. There was every evidence

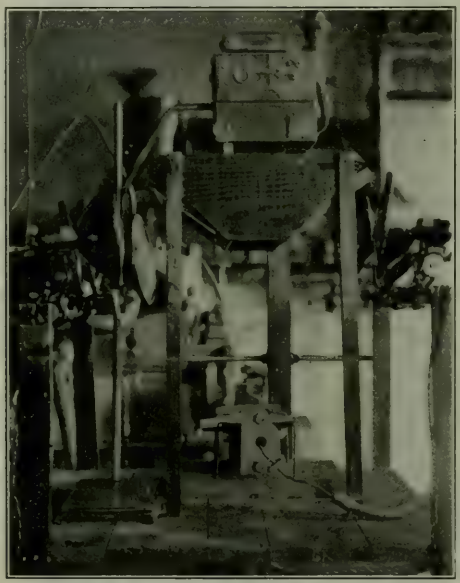


FIG. 1—THE ARRANGEMENT OF THE CAMERA WHICH WAS USED TO MAKE THE PHOTOGRAPHS OF MANIFOLD CONDITIONS

of the existence of eddies, whorls and impacts of considerable magnitudes at various points in the passage. After experimenting a bit, it was decided to stop guessing, and devise a means of making visual observations

[1] M.S.A.E.—Engineer in charge of the carbureter division, Stewart-Warner Speedometer Corporation, Chicago.

FIG. 3—CONDITIONS EXISTING IN THE MANIFOLD WITH THE THROTTLE OPEN SLIGHTLY

of the paths followed by the several portions of the air stream.

One of the passages being considered was half-sectioned in a plane about which the passage was symmetrical; that is, a plane containing the axes of the several parts of the passage. This method of making the cut causes the least disturbance of the flow lines in the sectioned member, as compared with those in the complete passage.

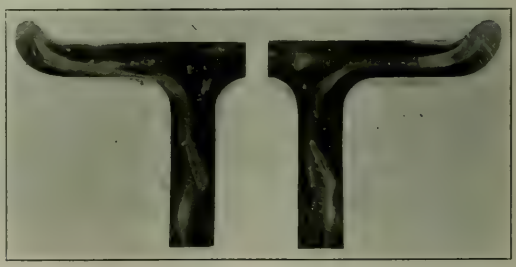


FIG. 4—MANIFOLD CONDITIONS WITH THE THROTTLE APPROXIMATELY HALF OPEN

A flat glass plate was then cemented on to complete the half-passage. With the outlet end of such a passage connected to an engine intake, any sort of flow encountered

FIG. 2—PHOTOGRAPH OF A MANIFOLD HAVING A COMPARATIVELY LONG RISER SHOWING HOW THE FLOW IN THE RISER IS CHANGED BY VARYING THE ANGULAR POSITION OF THE THROTTLE

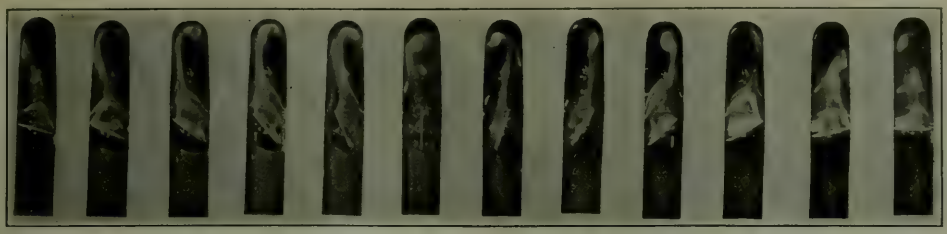


FIG. 7—PHOTOGRAPHS TAKEN WHILE THE THROTTLE IS ROTATING THROUGH 180 DEG.

in engine practice can be reproduced. It then only remained to introduce a comparatively non-volatile liquid that readily wets glass, such as gasoline, with the entering air, to cause a tracery of fine sharply defined lines

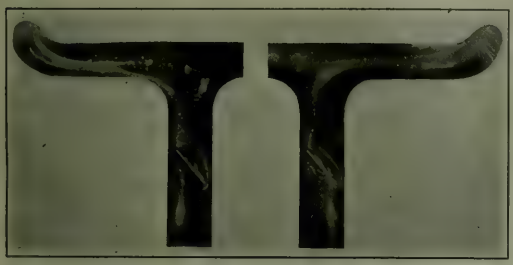


FIG. 5—OPENING THE THROTTLE STILL FURTHER HAS NOT PRODUCED ANY MATERIAL CHANGE IN THE MANIFOLD CONDITIONS

on the glass. These follow the air-flow lines faithfully and permit one to make valuable studies of passage flows. The application of the information obtained with this method of observation has proved that the tracery seen on the glass sufficiently indicates the flow lines followed in the middle plane of the complete full-section passage.

Following the completion of the work for which the set-up was made one of my assistants suggested that we apply the same method of observation to typical intake manifolds and cylinder combustion-chambers. The illustrations in the paper represent a portion of these latter observations.

Fig. 1 shows the photographic set-up used for recording purposes. A 3¼ x 4¼-in. Graflex camera is supported to point directly down upon the glass wall of the half-passage. A framework supports two rectangular mirrors which are used to reflect the light from a group of spotlights, in lines nearly normal to the glass on which the tracery appears. A black paper mask, cut to the outline of the passage, keeps the images of the lamps off

FIG. 6—A WIDE-OPEN THROTTLE RESULTING IN IDEAL FLOWS IN THE TWO INTAKE BRANCHES

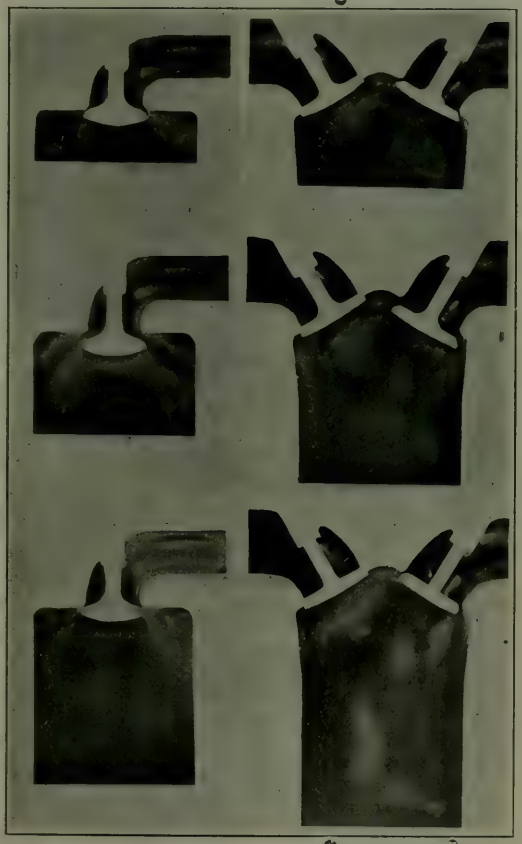


FIG. 8—INTAKE FLOW IN TWO TYPICAL VALVE-IN-THE-HEAD CYLINDERS

the camera screen. The reflection and refraction of the light at the fine liquid streams on the glass, cause their positions to be defined sharply on the camera screen. It has been found that, while complete detail is obtained

with intense illumination and short exposure, the best general purpose records result from an exposure of from 5 to 10 sec., with reduced illumination. This latter method gives a flatter, softer negative, but one which shows the general and more important flow lines to better advantage.

Fig. 2 illustrates what happens in a manifold with a comparatively long riser. In this group the throttle is taken through a half-revolution by considerable increments. The significant revelation here is the small effect upon conditions in the horizontal branch, resulting from a complete reversal of the throttle angular position, even though such change materially alters the flow in the riser. The whirling set up in the stream as it enters the outlet bend should be noticed and also that the major portion of the fuel hugs the lower wall of the branch,

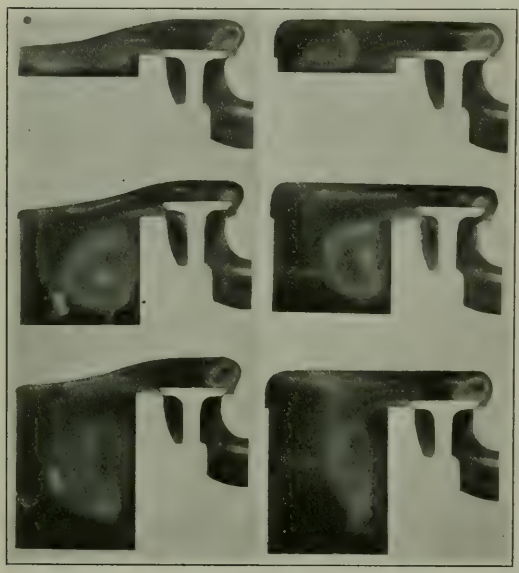


FIG. 9—INTAKE FLOW IN TWO FORMS OF L-HEAD COMBUSTION SPACES

beginning at the tee itself. This latter point, it will be remembered, was well shown by W. S. James at the Summer Meeting. The pictures in this group are typical of the photographic results with strong illumination and short exposure.

Less intense illumination and an exposure of about 5 sec. were used in making the next set of records of conditions in a typical intake with a short riser. In Fig. 3 and the others immediately following, the views are grouped to show the direct effects of throttle valve deflection upon the flows in the two branches. In considering each of these views, it should be borne in mind that the liquid filaments lie in and are forced to travel toward the low-pressure regions, in the same way that the earth's atmosphere flows to the regions of lowered pressure. Thus, the light streaks and areas in the illustration represent the low-pressure or high-velocity portions of the stream, and the dark places those regions of relatively high pressure. In Fig. 4 the throttle is opened slightly farther, and the reason why liquid distribution to the branches is sometimes imperfect is shown very clearly by the presence of liquid in the non-active outlet of the tee in one case and not in the other.

In Fig. 5 the throttle is opened still farther, with no material change in the general condition. A further cause of unequal distribution among cylinders is shown to reside in the whirling set up in the bends forming the manifold outlets. It is seen that in the two ends of the pipe the concentrations of liquid occupy somewhat different positions. Furthermore, when the whirling charge reaches the usual siamesed valve-ports, the chances are about 20 to 1 that one cylinder of the pair will receive more of this concentrated fuel stream than the other. It seems that a useful control of this phase of distribution would result, in any one case, from altering the lengths of the curved portions at the manifold outlets. Fig. 6 finishes this group, and shows open-throttle which, of course, results in perfectly identical flows in the two branches, provided the carbureter is shaped and mounted so as to permit it.

Fig. 7 shows the same form of manifold as that just preceding, but sectioned through the riser in a plane at right angles to the outlets of the tee. At the top of each view, one is looking directly into a branch. Also, the throttle spindle lies in the same plane as the branches. This is an effective arrangement for insuring equality of distribution to the tee outlets, but it also results in an energetic whirling or rotation of the whole stream, beginning at the tee, and persisting throughout the whole remaining length of the passage.

Here the throttle is rotated through 180 deg., to show completely its deflecting action. In making these records, the liquid was introduced in a thin film traveling along the surface of the glass; while in the others it was merely sprayed into the air-stream. This was done to bring out more clearly the behavior of the air-stream at the throttle valve. It is interesting to note how coming events cast their shadows before them at the upstream side of the throttle. At open-throttle the entering edge of the 1/16-in. thick valve is enveloped in a region of high pressure possessing a curiously alluring but apparently empty form; while at small angles from the open position, this region has sections suggesting a thick airfoil. The flow, with respect to its rotational direction in the branches, is very unstable at open-throttle, first whirling in one direction and then the other, resulting, in this photographic record, in what appears to be a symmetrical figure. These exposures had a duration of from 9 to 10 sec.

In Fig. 8 we have intake flow in two typical valve-in-head cylinders. The three views of each cylinder are intended to represent the beginning, the middle and the end of the suction stroke. Note particularly the forms and locations of the whorls at small clearances, and how they die out, so far as any concerted internal motion in the mass is concerned, as the piston is moved out. From this showing, it seems reasonable to suppose that this heterogeneous motion would not be amounting to much as a useful turbulence at the end of the compression stroke.

In Fig. 9 are corresponding views made in two forms of L-head combustion spaces. The enlarged and more persistent whorls, as compared with the valve-in-head cylinders, should be noticed as well as the fact that the combustion space in which the height is non-uniform being greatest over the valves, causes a greater portion of the total charge to participate in the whirling. The latter form is the superior performer in an engine, and an exaggeration of it might well be investigated.

Can Automobile Body Weight Be Reduced?

By Charles A. Heergeist[1]

Annual Meeting Paper *Illustrated with* Drawings

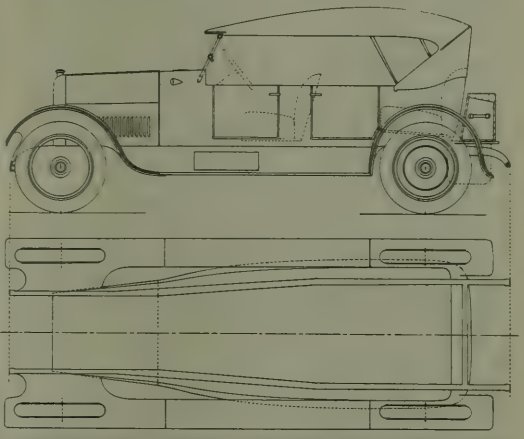
THERE is a demand for economy in the running costs of automobiles. Gasoline costs more than ever before. The heavy car consumes more fuel and wears out tires more rapidly. Custom builders have not been urged by their customers to make cars of light weight, possibly because those who can afford custom bodies are not so vitally concerned with the cost of gasoline and tires as the purchasers of lower-priced bodies produced in quantities. Smaller engines can be built, but if the work they have to perform remains the same, these engines must use an equivalent amount of fuel. The work of the automobile engine is proportionate to the weight of the car and passengers, and we cannot decrease the weight of the men and women who ride in our cars. The chassis engineers think the body builders should be doing something toward a reduction of weight.

Nearly all the varied industries which, cooperating with each other, go to form the automobile industry, are comparatively new and of independent origin. One of the few exceptions, perhaps, is the automobile body business, which grew out of the manufacture of carriages, buggies and wagons. Chassis engineers criticize the body engineering fraternity at the present time because they feel they have reached very nearly the limit in lightweight chassis construction, whereas they think the body engineers have made practically no advance in the last 10 years. As a group of body men, we may admit that this is a fairly correct statement of the case. Perhaps one of the reasons why so little has been done on the problem of reduction in body weight during the last 10 years is that so many problems of this kind had been solved in the days of the horse-drawn vehicle.

The phaetons, curricles, cabriolets, landaus, broughams and coaches of two decades ago were at the highest development they ever reached in style and construction. The quality of timber and all other material entering into carriage body building, as well as the character of workmanship, was of the very best that could be produced with the materials then available. This has been proved by examining carriage bodies built 50 and 100 years ago, which are still in good condition. Such bodies were built to stand the punishment of bad roads, cobblestones and deep ruts common years ago on country roads.

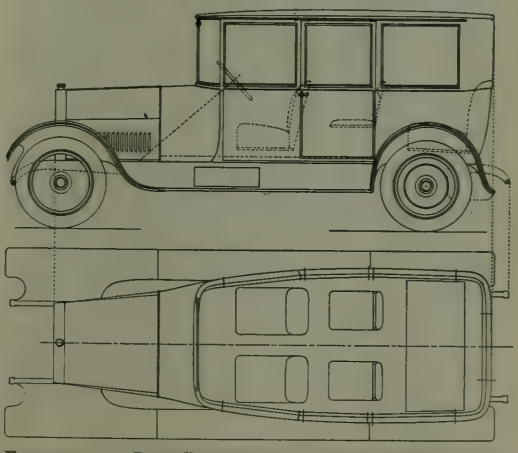
Buggies and two-passenger phaetons derived their lightness, combined with a remarkable carrying capacity, from the quality of timber and comparatively perfect workmanship entering into them. The landaus were the most troublesome bodies, considered in relation to light weight and carrying capacity, on account of the standing pillars being cut at the fence rails. But this very difficulty gave the body builders exact knowledge as to the dimensions of timber and the sizes of rocker plates required to sustain the weight of the body and the passengers, without any settling of the body on top of the fence rail, between the standing pillars.

[1]Technical editor, *Vehicle Monthly*, Philadelphia.



Elevation and Plan Drawings of a Four-Passenger Touring Car Body Having an Extreme Overall Width of 54 In.

It is decidedly necessary that an automobile body should have a solid foundation. Past experience taught body builders a good lesson when the leather-top landaus were in fashion. These bodies had the doors cut at the fence rail, and the rocker plates were sufficiently strong to prevent the doors from closing up at the fence rails, in other words, at the top of the doors. These rocker



Elevation and Plan Drawings of a Seven-Passenger Sedan Body Having a Maximum Width of 56 In.

plates were made ½ x 4½ and ⅝ x 4½ in. when the supports were 101 in. apart, which would correspond to what we call the wheelbase at present.

Application of Carriage Experience

This experience in the construction of open and closed carriage bodies was applied to automobile bodies, which is, in fact, the same as carriage work, and similar rules must be applied to their construction. Automobile bodies are constructed without rocker plates, and the frame has been substituted for them. Consequently, for the foundation of the body we have to depend on the body sills and the frame. Besides this, we must make a distinction between open and closed bodies, in other words, between touring cars and sedans.

The body builder's rule, then, must be not only to keep the body from settling so that the doors can open and shut without any hindrance, but also to keep the body from twisting. As the body builder is in no position to remedy such a condition by himself, he must work in conjunction with the chassis engineer from the beginning to the end, and each should consult the other as to the constructional details of the body and the frame.

If the frame is too weak, it will settle from the weight of the body and the passengers, and from the shocks resulting from uneven roadways. Consequently the frame should be in proportion to the weight it has to carry, with an extra allowance for the shocks caused by the rough roads. No automobile body, even though of the very best material and workmanship, will stand the twisting of a weak frame. It is bound to part at the joints, whether it is an open or a closed body.

Bodies can be built somewhat lighter to obtain a reduction of weight depending on the kind and style of bodies, but the body engineer can reduce the weight only under certain conditions, when these conditions are in his favor. First and most important is the carrying capacity of the frame. All others are only minor conditions.

A hindrance to lighter weight is the use of the same size of frame for a two-passenger runabout as for a six-passenger sedan. The frame is too heavy in the first case; when fitting a six-passenger sedan body on the same frame it may be too light. In other words, frames are frequently out of proportion to the weight of the body and the passengers. If a touring car frame is too weak the door joints at the top of the body will clinch tight, and the doors cannot be opened. This is one of the greatest inconveniences that can happen, especially in the case of accidents. The body engineer in such a case is helpless, no matter how strongly the body is built; the sills and entire body structure will settle if the frame does.

These defects also occur in closed bodies, such as sedans or limousines. If the frame is weak, the front standing pillar or coupé lock pillar on closed bodies will bend toward the door and close up the door joint, preventing the door from operating, besides weakening the body in all its joints. In all cases where the frame is not sufficiently strong the body engineer is helpless because the foundation is too weak to sustain the intended carrying capacity and withstand the road shocks. If the body engineer must build a body on a weak frame, he can avoid most of the trouble by using heavier sills or rocker plates on the inside edges of the sills or filling up the angular frame with stiff timber. This of necessity adds to the body weight.

The practice of using the same kind of frame for a two-passenger and a seven-passenger car is not to be recommended, as, in the case of the two-passenger car, the frame would be too heavy, and for the seven-passenger car it might be too light, and settling between the wheelbase supports might be the result. Reduction in the weight of automobile bodies may be possible, but the stability of the body on the frame must be retained. If the metal frame sags it carries the body with it at every downward movement; consequently the frame should be proportioned to rigidly support the weight of the passengers, and the body built on that frame should be as light as is consistent with stability.

According to the above observations, it is seen that the weight of bodies can be reduced only if the metal frame is designed as the real support of the weight of the passengers and the body. The weight can also be reduced if the frame is built in proportion to the amount of weight to be carried, the number of passengers and the style of bodies being considered. In the construction of closed bodies, however, such as sedans, coaches and broughams, very little weight can be saved if stability and lasting quality are to be retained.

An obstacle to lighter weight construction has sometimes been encountered in the widths of frames. French chassis builders have been content with a frame width of 28 in. across the front and 35½ in. across the rear. These frames are suitable for narrow bodies about 50 in. wide, outside measurement, the same as the horse-drawn broughams and coaches were made. This width of 35½ in. was tolerated by body builders, but the narrower the frame the wider the sills had to be made, because the entire length of the sills should rest on the frame to create a solid foundation. Suppose we have a frame 36 in. wide outside, and the width of body is 38 in. outside, with a 3-in. turn-under on each side. The recess caused by the narrow width of the frame when 36 in. wide, will be 11 in. on each side, or 13 in. when the sills have to rest on the frame, making the sills entirely out of proportion, and adding considerably to the weight. On account of the excessive amount of recess, the construction is weakened. American chassis engineers have made an improvement by widening the frame to 40 in. outside, a change which has strengthened the body and reduced its weight. If this width at the rear could be further increased for wide bodies, it would be an advantage to the body designer.

Chassis engineers have also made considerable improvement in the carrying capacity of the frame. In some instances, from the body designers' point of view, they have even gone too far, adding to the weight where it was not needed. A rule should be found to determine the carrying capacity of each frame, but this is difficult on account of the elasticity of the springs, the variability in the load carried, and the occurrence of road shocks. The old-time coach builder found out all he wanted to know by loading the body to its full capacity and then violently jolting it up and down.

Limitations in Weight Reduction.

The body engineer, of necessity, must work under certain limitations in any effort he makes to reduce body weight. There are some members of the body framework which must have certain sizes if strong and comfortable seats are to be provided for the passengers. Ample width and height of body are most important. If the width is unduly restricted the passengers will be uncomfortable, and the body must certainly be high enough to afford ample headroom. Both width and height add to the weight. This also applies to what is known as "knee room," which affects the length of the body and adds

considerably to the weight. The door and standing pillars must have a certain thickness where the windows move up and down, and a certain thickness to frame the doors and hold the door hinges and locks in their places.

Attention must be paid to the window regulators, which allow the body designer no leeway, since the lift occupies a certain space which cannot be reduced and still provide for the raising and lowering of the glass. Window regulators have supplied us with a convenience that car owners would not wish to dispense with, but they have added weight to the body besides their own.

Concealed door hinges are most desirable and practical, are invisible when the doors are closed and hardly visible when the doors are open. But additional space must be occupied to let them into the pillar, and at the same time the strength of the standing and door pillars must be preserved to prevent them from collapsing. The sizes of such pillars depend on the kind of concealed door hinges used and the pillars cannot be reduced in weight if the required strength is made the same as that of the door and side quarter glass lifts. When plain, straight or curved door hinges are used, the standing pillars can be reduced somewhat, but the amount of weight that can be saved here is so slight that it only counts in connection with other reductions. The weight of door locks has been reduced considerably, but when quality demands that the doors open and shut properly and easily, such locks must have some weight which cannot be reduced very much.

The parts of the body which add most to the weight, are the framework or frame structure of the body and the outside covering. The frame structure has been reduced almost to its limit, considering adequate strength for each part of the body, each part depending on the others to make a strong, solid structure. The sills on a body should not be less than $1\frac{1}{2}$ in. in thickness and the width must be such that both sills rest on the frame. The top rails, cross bars and curves must have a certain size, below which the weight cannot safely be reduced. The outside covering of the body in present practice is either solid wood panels, sheet aluminum, sheet steel, or plywood. Wood panels are only used in connection with aluminum and for custom work. Sheet steel is preferred when a great number of bodies are produced in one model. In the past, plywood has been used chiefly for the tops on closed bodies, but it can be used to advantage where panels of other materials have formerly been used, if it can be shown that weight is saved thereby. For ease of working the metal and its light weight, aluminum has the preference.

I am sufficiently optimistic to believe that ways will be found to build lighter cars and lighter bodies. I have stated some of the limitations under which the body engineer must work, and it is only within such limits that any reductions in body weight can be made.

FARM POWER MEETING AND DINNER

(*Concluded from page* 280)

It is desirable that there should be on every farm electric lighting, power washing and every other similar convenience. Agriculture must be sufficiently remunerative to keep the boys and the girls on the farm. Marketing is just as important a function as production. The farmer recognizes that there must be community organization of the social phases of his life. The farmer does not desire to eliminate the middleman. He will insist upon modern agricultural equipment and upon the establishment and maintenance of a shorter route between producer and consumer. He wants more for the product of his toil, believing that then all others as well will receive more.

W. H. Stackhouse, president of the National Implement and Vehicle Association, whose members produce 93 per cent of the farm implement output of this country, addressed the members on the immediate problems of the farm operating equipment industry. He said that the $5,000,000,000 loss, which has been alluded to frequently as having been experienced by the farmers as a result in the shrinkage of the market value of their products, is a bookkeeping and not an actual loss. The farmers' losses cannot be determined before all their products on hand shall have been sold. Today the farmer has a tremendous buying power. He has never been and never will be a profiteer or striker.

Mr. Stackhouse quoted the Federal Trade Commission report to the effect that during the period from 1913 to 1918 the average price of farm implements increased 72 per cent. In this time all other commodities supplied to the farmer increased in price 97 per cent, and the farm products themselves 118 per cent. Considering the years 1913 to 1920, the increases were as follows: farm implements, 78 per cent; farm products, 112 per cent; labor, 115 per cent; other commodities, 144 per cent. Mr. Stackhouse said that farm implement prices will be reduced when the replacement cost in manufacture goes down. He paid a splendid tribute to standardization for its value in intelligent selective elimination of unnecessary sizes and immaterial differences in elements involved in manufacture. He said that work of this nature had saved the American farmer $10,000,000 last year. The Federal Trade Commission has reported that 22,000 different types of farm implement were being produced.

Fred Glover was most amiable and effective as toastmaster at the dinner.

The 1921 Standards Committee

IN view of the several broadening fields of standardization work, and of experience had in procedure, the intention has been to organize the Standards Committee in such a way as to maintain from year to year Divisions whose jurisdictions will be of a nature permitting prompt reference of almost any subject that may come up to some one Division. The Divisions are constituted of two classes, one representative of the respective automotive industries, and the other of parts and materials producers, arranged in a general grouping.

Matters pertaining to but one of the automotive industries will be referred to the Division representing it. Subjects that relate to two or more automotive industries will be assigned to the appropriate parts or materials Division and considered by this Division in conjunction with the respective automotive Divisions. For the purpose of strengthening and facilitating the work of the whole Committee, two Vice-Chairmen of the Standards Committee and a Vice-Chairman for each Division have been appointed. This will make more certain the attendance of a regularly appointed presiding officer at all Division sessions, as well as of the Chairman or a Vice-Chairman of the whole committee.

The Aeronautic Division and its several Subdivisions are retained practically as they were in 1920. The Isolated Electric Lighting Plant Division is broadly representative industrially of the field of farm and other isolated plant lighting which has expanded considerably during the past 2 years. The Motorboat Division is a continuance of the previous Marine Division. The Motorcycle, the Stationary Engine, the Tractor and the Truck Divisions are substantially the same as before. The 1920 Electric Transportation Division was divided into Subdivisions representative of electric passenger-cars and trucks, industrial trucks and tractors and the storage batteries used in these vehicles. It has been decided to discontinue temporarily standardization work in connection with industrial trucks and tractors as such, owing to lack of cooperative effort of the manufacturers in this field. The activities of the Electric Vehicle Division will refer to road vehicles of the type indicated by its name. The Storage Battery Division will handle all storage battery matters coming before the Standards Committee. Largely as a result of the very successful body-engineering session of the Society held in January and the interest manifested by designers and manufacturers, the Passenger Body Division has been created to take up suggestions for standardization of some phases of body construction and installation. It is expected that this Division will provide adequate means through which manufacturers can maintain effective cooperation for the solution of many problems in connection with the production of automobile bodies. The Lighting, Ball and Roller Bearings, Electrical Equipment, Engine, Frames, Iron and Steel, Non-Ferrous Metals, Radiator, Springs, Transmission and Lubricants Divisions are virtually the same as they were in 1920. The Miscellaneous Division, which has been active for many years, has been divided into the Parts and Fittings Division and the Screw Threads Division. Subjects pertaining principally to screw-thread specifications are usually of such a specialized nature as to warrant consideration of them in a separate Division. The new Chain Division is a continuance in combination of the Roller Chain Division and the Silent Chain Division. Although there is considerable inherent difference between the two classes of chain, it is desired that joint consideration of them shall be had. When matters relating strictly to one or the other class come before the Division, a special Subdivision will handle them.

Regulations Governing Standardization

The work of the Standards Committee is increasing in volume and scope, and requires more and more definite systematizing of procedure in the formulation and recommendation of standards. The Regulations Governing the Standards Committee have been revised as necessary and considered advisable during the past few years. They have been extended somewhat recently to read as follows:

The Standards Committee of the Society of Automotive Engineers may be composed of members or non-members of the Society.

FUNCTIONS

The Standards Committee under the discretion of the Council shall have jurisdiction over the formulation of all standards and recommended practices which may come before the Society for final adoption.

It may also be charged with such special deliberations or investigations as the Council may deem advisable or necessary for the preparation of authoritative reports.

The results of these investigations may, in the discretion of the Council, be made the subject of special reports.

ORGANIZATION

The Standards Committee shall act under the direction of a Chairman and two Vice-Chairmen, who shall be ex-officio members of each Division, and shall be assisted by a Standards Manager.

The whole Committee shall be resolved by the Council into a number of Divisions, each charged with the consideration of a group of subjects. Each Division shall be presided over by a Chairman or in his absence by a Vice-Chairman.

Any Division may be resolved further into such Subdivisions as the Division Chairman may deem expedient.

APPOINTMENTS

Appointments to membership on the Standards Committee shall be made annually by the Council in conference with the Chairman of the Standards Committee.

Interim appointments may be made by the Council.

The Chairman and the two Vice-Chairmen of the Standards Committee and the Chairmen and Vice-Chairmen of its Divisions shall be designated annually by the President of the Society.

The President and the Secretary of the Society shall be ex-officio members of the Standards Committee and of its Divisions.

PERSONNEL

Subdivisions—The Chairmen of Subdivisions shall be appointed by the respective Division Chairmen and shall preferably be members of the same Division.

Subdivision members may be members or non-members of the Society.

Appointments on Subdivisions shall be subject to the approval of the Standards Committee Chairman.

Division personnel in so far as feasible shall be representative of at least two groups, producers and users.

Divisions—Conferees of Divisions shall include all appointees who are not members of the Society. A conferee shall upon qualifying as a member of the Society

become a member of the Division. Conferees shall have no vote, but may serve in an advisory capacity and participate in discussions at all meetings.

One or more representatives of any one company may be appointed to Divisions or Subdivisions.

PROCEDURE

The order of business at Division or Subdivision meetings shall be:

Attendance registration
Approval of minutes
Subjects in progress
Revision of existing standards
Proposal of new subjects
Place and date of next meeting

In Subdivision—Reports on proposed new standards or revision of existing standards may issue from a Subdivision as preliminary reports only, and shall be submitted to the respective Division for approval.

In Division—Subdivision reports may be amended or referred back to the Subdivision by the Division.

However initiated, a proposed new standard or revision of an existing standard must issue as a report from that particular Division within whose province such matters properly belong, under assignment by the Council of the Society.

No action affecting the substance of a report shall be taken by any division except at a meeting called for that purpose or, at the discretion of the Standards Committee Chairman, by letter ballot of the Division. Approval of a report by letter ballot shall be by majority of the voting members of the Division. Voting by proxy is not permissible.

Reports shall consist generally of complete but concise statements of the practices and constructions, as recommended, together with such illustrations as may be necessary. There should be appended also explanatory remarks of the recommendations made.

A majority of voting members of a Division shall constitute a quorum thereof.

In the case of more than one member of the Division being associated with a given company, only one vote shall be cast on behalf of such members in Division meetings.

Dissenting members have the right to present minority reports individually or jointly.

All Division actions in meetings of the Division not approved by the vote of all the members of the Division shall be submitted by letter ballot to all the voting members of the Division.

In Standards Committee—Reports of the Division shall be submitted to the Standards Committee for approval at regular or special sessions.

Upon approval by the Standards Committee in original or amended form, Division reports shall be transmitted, with a statement of the action thereon, to the Council for approval in original or amended form for submission to the Society.

Fifteen members of the Standards Committee shall constitute a quorum.

Only members of the Standards Committee shall vote at Standards Committee meetings. The majority of those voting shall be necessary to approve a report. Voting by proxy is not permissible.

In Society Meeting—Division reports, when approved by the Council, shall be submitted to the Society for discussion at a duly called regular or special meeting.

Division reports may be amended or referred back with instructions.

A majority of the votes cast at a Society meeting by Society Members is necessary to approve reports for submission by letter ballot to the Members of the Society.

The Letter Ballot—Before adoption Division reports approved at a Society meeting shall be submitted by letter ballot to the voting members of the Society.

The letter ballot shall provide for the recording of affirmative and negative votes and waivers.

The letter ballot shall be returnable to the Secretary of the Society within 60 days following the Society meeting.

The letter ballots shall be opened and recorded 60 days following each Society meeting by three tellers appointed by the President of the Society.

The adoption of a report shall be determined by the majority of the letter ballots cast. Voting by proxy is not permissible.

MEETINGS

Committee Meetings—Meetings of the Standards Committee shall be held on the first day of or on the day preceding each Annual and each Semi-Annual Meeting of the Society. Special meetings may be held by direction of the Council.

Division Meetings—A meeting of a Division may, with the approval of the Standards Manager and the Secretary of the Society, be called on 10 days' notice, at the suggestion of the respective Division Chairman, or may be called on 10 days' notice by direction of the Secretary of the Society.

COMMITTEE RECORDS

Attendance—The Standards Manager or other representative of the Standards Department of the Society shall record the minutes, including the names of those in attendance, of Division or Subdivision meetings. In the absence of such representative, a suitable record of the proceedings of a meeting of a Division or Subdivision or of members thereof, shall be made by or by direction of the Chairman or Chairman pro tem of the meeting.

Members or conferees on Divisions or Subdivisions who are absent from two consecutive meetings shall be automatically discontinued from membership thereon except for adequate reasons, submitted in writing to the office of the Standards Committee or to the Division or Subdivision Chairmen.

Depository for Records—The Chairman of any Division or Subdivision or member thereof shall, after completion of work on any subject referred to the Division, transmit to the office of the Standards Committee any papers or correspondence relating thereto he may have in his possession.

MISCELLANEOUS

Publicity—A Division or Subdivision or a member thereof shall not have the right to issue matter for publication through other than the regular Society channels, unless so authorized for reasons of weight by the Council.

Stationery—Official correspondence, especially requests for information as to practice, should be conducted on official stationery, which will be furnished by the Secretary of the Society as necessary to Chairmen and members of Divisions or Subdivisions for use in conduct of special work.

Expenditures—No obligation for expenditures other than postage will be assumed by the Society unless such expenditure shall have been incurred in pursuance of previous authorization by the Council, and then only within specific fixed amounts.

Work in Progress

There are approximately 200 subjects before the Standards Committee, including new assignments and proposed revisions of existing S.A.E. Standards and Recommended Practices. The work of revision is fundamentally important. The standards of the Society must keep pace with the progress in the industrial arts and sciences. The automotive and allied industries are enter-

ing upon a new era which will bring forth an improved and more healthy state of production, and the existing standards and those now being developed are and will be essential in securing adequate conservation of labor and material, reduction of costs, and improvement in quality of product.

THE PERSONNEL

The Standards Committee of the Society for the year 1921 is listed below in substantially complete form.

STANDARDS COMMITTEE

B. B. Bachman, *Chairman*
W. A. Chryst, *Vice-Chairman*
W. R. Strickland, *Vice-Chairman*

AERONAUTIC DIVISION

H. M. Crane, *Chairman*
Glenn L. Martin, *Vice-Chairman*

C. DeF. Chandler	L. B. Lent
V. E. Clark	G. C. Loening
W. L. Gilmore	G. J. Mead
L. M. Griffith	W. H. Phipps
G. E. A. Hallett	H. C. Richardson
J. L. Harkness	W. T. Thomas
J. C. Hunsaker	R. H. Upson
F. M. Kraus	C. M. Vought

P. W. Wittemann

Controls Subdivision

V. E. Clark, *Chairman*

L. B. Lent	G. C. Loening

Dope, Cement, Varnish and Glue Subdivision

W. T. Thomas, *Chairman*

J. C. Hunsaker	C. E. Waters
J. J. Moosmann	P. W. Wittemann

Materials Testing Subdivision

G. L. Martin, *Chairman*

J. C. Hunsaker	H. C. Richardson
J. B. Johnson	C. E. Waters
J. S. Macgregor	P. W. Wittemann

Performance and Testing Subdivision

G. L. Martin, *Chairman*

V. E. Clark	L. B. Lent
H. M. Crane	G. C. Loening
J. C. Hunsaker	H. C. Richardson
Alex Klemin	W. T. Thomas
K. M. Lane	C. M. Vought

Powerplant Subdivision

G. E. A. Hallett, *Chairman*

F. W. Caldwell	F. M. Kraus
Frederick Charavay	L. B. Lent
L. M. Griffith	G. J. Mead
E. J. Hall	C. M. Vought

L. M. Woolson

Tires and Wheels Subdivision

C. M. Vought, *Chairman*

J. V. Costello	J. C. Hunsaker
J. L. Harkness	L. B. Lent

Wire and Fittings Subdivision

G. L. Martin, *Chairman*

J. V. Costello	G. C. Loening
J. C. Hunsaker	H. C. Richardson

BALL AND ROLLER BEARINGS DIVISION

W. R. Strickland, *Chairman*
F. W. Gurney, *Vice-Chairman*

W. L. Batt	G. L. Miller
G. R. Bott	E. Nides
E. R. Carter	H. J. Porter
D. F. Chambers	R. G. Schaffner
F. G. Hughes	A. T. Sturt

R. E. Wells

CHAIN DIVISION

William F. Cole, *Chairman*
A. Ludlow Clayden, *Vice-Chairman*

W. J. Belcher	J. A. Kraus
A. E. Brion	F. L. Morse
H. F. Funke	H. S. Pierce
J. C. Howe	L. M. Wainwright

V. C. Young

ELECTRIC VEHICLE DIVISION

E. L. Clark, *Chairman*
Karl Probst, *Vice-Chairman*

G. M. Bacon	F. E. Queeney
J. G. Carroll	Charles A. Ward

ELECTRICAL EQUIPMENT DIVISION

A. D. T. Libby, *Chairman*
F. W. Andrew, *Vice-Chairman*

Azel Ames	T. L. Lee
W. A. Chryst	B. M. Leece
W. A. Frederick	C. Marcus
C. F. Gilchrist	R. G. Thompson
W. S. Haggott	A. H. Timmerman

ENGINE DIVISION

H. C. Snow, *Chairman*
J. B. Fisher, *Vice-Chairman*

R. J. Broege	C. E. Sargent
W. A. Frederick	A. J. Scaife
A. F. Milbrath	E. O. Spillman

FRAMES DIVISION

E. A. DeWaters, *Chairman*
F. R. Pleasonton, *Vice-Chairman*

J. M. Cook	O. B. Harman
L. J. Frelick	E. L. Larson

IRON AND STEEL DIVISION

F. P. Gilligan, *Chairman*
W. C. Peterson, *Vice-Chairman*

R. M. Bird	C. G. Heilman
C. N. Dawe	C. T. Moody
P. H. DeLong	J. H. Nelson
E. L. French	G. L. Norris
W. F. Graham	C. F. W. Rys
H. L. Greene	H. J. Stagg
Fletcher Harper	Samuel Tour

ISOLATED ELECTRIC LIGHTING PLANT DIVISION

L. S. Keilholtz, *Chairman*
G. E. Tubbs, *Vice-Chairman*

T. P. Chase	E. B. Newill
A. S. Denes	C. E. Reddig
G. M. Gardner	E. L. Russell
L. W. Heath	Samuel Wilbur

LIGHTING DIVISION

C. E. Godley, *Chairman*
W. A. McKay, *Vice-Chairman*

Paul Bauder	C. A. Michel
T. C. Carruthers	Henry Platz
F. M. Holden	E. S. Preston
William E. Metzger	C. H. Sharp

J. C. Stearns

LUBRICANTS DIVISION

H. C. Mougey, *Chairman*
W. E. Jominy, *Vice-Chairman*

A. P. Eves	W. H. Herschel

G. B. Upton

MOTORBOAT DIVISION

Joseph Van Blerck, *Chairman*
H. H. Brautigam, *Vice-Chairman*

Irwin Chase	William J. Deed
G. F. Crouch	H. E. Fromme
G. C. Davison	W. C. Morehead

MOTORCYCLE DIVISION

W. S. Harley, *Chairman*
C. B. Franklin, *Vice-Chairman*
A. J. Hall — W. G. Henderson
F. W. Schwinn

NON-FERROUS METALS DIVISION

J. J. Aull, *Chairman*
Dr. E. Blough, *Vice-Chairman*
W. J. Burr — Charles Pack
G. K. Elliott — H. P. Parrock
E. S. Fretz — W. C. Peterson
Zay Jeffries — W. B. Price
H. C. Mougey — E. S. Wheeler
W. A. Woodward

PARTS AND FITTINGS DIVISION

Clarence Carson, *Chairman*
F. G. Whittington, *Vice-Chairman*
L. G. Bayrer — C. W. Spicer
H. Jandus — W. R. Strickland
W. C. Keys — H. T. Thomas

PASSENGER BODY DIVISION

E. G. Budd, *Chairman*
E. Glenn Simpson, *Vice-Chairman*
William E. Biddle — George Grimm
J. S. Burdick — George W. Kerr
F. C. Chapman — George J. Mercer
G. E. Goddard — A. J. Neerken
H. C. Nelson

RADIATOR DIVISION

J. D. Harris, *Chairman*
C. S. Sage, *Vice-Chairman*
D. L. Britten — C. T. Perkins
H. C. Harrison — G. H. Pettit
H. B. Knap — K. F. Walker
Charles Oppe — E. E. Wemp

SCREW THREADS DIVISION

E. H. Ehrman, *Chairman*
O. B. Zimmerman, *Vice-Chairman*
Earle Buckingham — Luther Burlingame
E. Burdsall — W. R. Mitchell
A. J. Scaife

SPRINGS DIVISION

R. A. Schaaf, *Chairman*
S. P. Hesse, *Vice-Chairman*
H. R. McMahon — Gustof Peterson
W. M. Newkirk — F. A. Whitten

STATIONARY ENGINE DIVISION

Theo. C. Menges, *Chairman*
L. F. Burger, *Vice-Chairman*
H. N. Edens — F. C. Hobart
H. C. Gibson — V. E. McMullen
T. A. Hicks — C. J. Nelson
L. M. Ward

STORAGE BATTERY DIVISION

Bruce Ford, *Chairman*
G. M. Bacon, *Vice-Chairman*
W. H. Bancroft — W. E. Holland
E. L. Clark — C. T. Klug
R. I. Ellis — I. M. Noble

TRACTOR DIVISION

E. A. Johnston, *Chairman*
H. C. Buffington, *Vice-Chairman*
J. S. Davis — M. B. Morgan
A. H. Gilbert — C. B. Rose
R. O. Hendrickson — A. W. Scarratt
C. Edward Johnson — O. W. Sjogren
J. Mainland — L. W. Witry
G. A. Young

TRANSMISSION DIVISION

A. W. Copland, *Chairman*
A. C. Bryan, *Vice-Chairman*
J. B. Foote — W. C. Lipe
L. C. Fuller — C. E. Swenson
A. A. Gloetzner — S. O. White

TRUCK DIVISION

A. K. Brumbaugh, *Chairman*
F. A. Whitten, *Vice-Chairman*
D. L. Arnold — C. O. Guernsey
W. M. Britton — M. C. Horine
J. R. Coleman — H. B. Knap
F. W. Davis — A. J. Scaife

OIL-BURNING VESSELS

FIGURES compiled by the American Petroleum Institute from the 1920 and 1919 reports of the bureau of navigation, Department of Commerce, show a total of 1367 vessels in the American merchant marine of 500 gross tons and over equipped for burning oil fuel in 1920, as against 762 vessels in 1919. The 1920 figures are corrected to Oct. 1, 1920, and the 1919 figures are for the fiscal year ended June 30, 1919. The figures follow:

	Number of Vessels	Gross Tons
1920	1,367	6,462,411
1919	762	3,510,465
Increase, 1920	605	2,951,946

The increase of 605 vessels, representing 2,951,946 gross tons, is a significant index to the growth of marine requirements for fuel oil for the period. Included in the total figures given are 230 tank vessels, aggregating 1,334,127 gross tons, in 1920, and 162 tankers, aggregating 905,237 gross tons, in 1919, equipped for burning fuel oil. Of the aggregate number of vessels equipped for burning fuel oil in 1920, 946, with a gross tonnage of 4,334,428 tons, were Shipping Board vessels.

AIR MAIL SERVICE

THE United States was the first country in the world to establish a regular Air Mail Service, that between Washington and New York City, which was opened May 15, 1918. Since then the Service has been extended to San Francisco, St. Louis and Minneapolis and St. Paul. Thirty-five cargo-carrying mail planes are in the air each day, flying a total of 8000 miles.

Since the experimental line between Washington and New York City was started, England, France, Belgium, Germany, Italy, Switzerland, Czecho-Slovakia and the Scandinavian countries have established air mail routes, the most notable of which are those connecting London and Paris, Copenhagen, London and Amsterdam, Paris and Prague and Berlin, Hamburg and Munich.

The coast-to-coast air mail provides the means for greatly reducing the time of rail transportation, and the introduction of night flying which is imminent will enable letters to be transported from New York City to San Francisco in two days or less. During the calendar year 1920 the Air Mail Service carried about 103,000,000 letters.

PIGEONS IN NAVAL AVIATION

THE Navy Department has issued a statement giving statistics recently compiled concerning the part played by pigeons in Naval Aviation during the war. It is stated that during the last 10 months of the war United States Naval pigeons delivered 219 messages from seaplanes forced to land at sea and which were without any other means of communication.

Applicants *for* Membership

The applications for membership received between Jan. 28 and Feb. 21, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ARDERN, JAMES S., service manager, Northway Motor Sales Co., *Boston.*

ARMINGTON, A. P., superintendent and engineer, Euclid Crane & Hoist Co., *Euclid, Ohio.*

BERGLING, NILS K. A., draftsman, Holt Mfg. Co., *Stockton, Cal.*

COBB, E. E., service and sales manager, U. S. Malleable Iron Co., *Toledo.*

COLE, W. F., chief inspector automobile body department, Osgood Bradley Car Co., *Worcester, Mass.*

COMFIELD, EINAR A., chief draftsman, Available Truck Co., *Chicago.*

CUMMINGS, STANLEY R., instructor, Massachusetts Institute of Technology, *Cambridge, Mass.*

DELANY, HOWARD S., partner, Delany & Co., *Tacony, Philadelphia.*

DELAVAL-CROW, THOMAS CLIVE, chief engineer, New Departure Mfg. Co., *Bristol, Conn.*

EATON, WILLIAM S., director body department, Dupont Motors, Inc., *Moore, Pa.*

FORDYCE, THOMAS N., district representative, Willard Storage Battery Co., *Cleveland.*

GIBSON, RICHARD, JR., technical superintendent, Lancaster Tire & Rubber Co., *Lancaster, Ohio.*

GOTTRON, ROBERT E., chief engineer, Weger Aeronautical Motor Co., *Cleveland.*

GROSS, EDWARD L., vice-president, Perolin Co. of America, *Chicago.*

HARDY, LEO J., draftsman, Osgood Bradley Car Co., *Worcester, Mass.*

HARVEY, CHARLES A., designing draftsman, Erie Motor Truck Mfg. Co., *Erie, Pa.*

HENRY, GUY P., chief engineer, Studebaker Corporation, *Detroit.*

HOOD, CLIFFORD F., superintendent, electrical cable works, American Steel & Wire Co., *Worcester, Mass.*

HUBBARD, HENRY M., designer, tank, tractor and trailer division, district engineering office, Ordnance Department, *Cleveland.*

HULT, DEWEY E., mechanical draftsman, Toro Mfg. Co., *Minneapolis.*

KAZEY, A. R., charge of engineering department, Ross Gear & Tool Co., *Lafayette, Ind.*

KNAPP, ARCHER L., assistant body engineer, Packard Motor Car Co., *Detroit.*

LA GUIRE, RAYMOND F., laboratory assistant, Joseph Tracy, *New York City.*

LANE, KENNETH M., aeronautical engineer, Dayton-Wright Co., *Dayton, Ohio.*

LARKIN, WALTER P., superintendent jobbing division, Bock Bearing Co., *Toledo, Ohio.*

LUTMAN, HARRY L., machine designer, Western Electric Co., Inc., *Chicago.*

MCCONNELL, WILLIAM G., assistant sales manager, Oklahoma Auto Mfg. Co., *Muskogee, Okla.*

MACVICHIE, DONALD, general manager, Motor Car Service Bureau, *Danville, Ky.*

MEYER, GEORGE L. N., 796 Marietta Avenue, *Milwaukee, Wis.*

NAKADA, KYOICHI, assistant chief designer, Tokyo Gas & Electric Industrial Co., Ltd., *Tokyo, Japan.*

OSTERMAN, HANS, president, Aktiebolaget Scavia-Vabis, *Stockholm, Sweden.*

OUTCALT, WILLIAM J., head of standard parts department, General Motors Corporation, *Detroit.*

PARRISH, RIAL T., chief engineer, Two-Way Plow Tractor Co., *Dayton, Ohio.*

PHILLIPS, GEORGE C., body engineer, Auto Body Co., *Lansing, Mich.*

PROPER, LESLIE E., body designer, Durant Motors, Inc., *Long Island City, N. Y.*

REEVE, EDWARD, superintendent, Wolseley Motors, Ltd., Adderley Park, *Birmingham, England.*

SHAFER, WILLIAM H., secretary and superintendent, Ahrens-Fox Fire Engine Co., *Cincinnati.*

SHIDLE, NORMAN G., editorial staff, *Automotive Industries, New York City.*

SOUTHARD, SEWALL CLARKE, student, Tri-State College of Engineering, *Angola, Ind.*

WEINERT, RICHARD H., efficiency engineer, Studebaker Corporation, *Detroit.*

WESTMAN, E. E., secretary and treasurer, Kant Kut Tube Products Co., *Indianapolis.*

WHEAT, E. F., superintendent, Y. M. C. A. Automobile School, *St. Louis.*

WHITE, EARL A., editor, *Farm Implement News, Chicago.*

WILLIAMS, IVOR H., assistant engineer, Weger Aeronautical Motor Co., *Cleveland.*

WILLIAMS, J. J., general production superintendent, Federal Rubber Co., *Cudahy, Wis.*

WITTE, OTTO A., secretary and chief engineer, American Bureau of Engineering, Inc., *Chicago.*

WITTER, HARRY L., lubricating engineer, Standard Oil Co., *Detroit.*

WOOD, ELLERY CHANNING, engineer, Petroleum Heat & Power Co., *Boston.*

WOOD, E. ELLSWORTH, engineer, Miniature Incandescent Lamp Corporation, *Newark, N. J.*

WRIGHT, WILLIAM E., experimental engineer, Waukesha Motor Co., *Waukesha, Wis.*

YOUNGS, ARTHUR, manager, Youngs & Co., *Newburgh, N. Y.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Jan. 10 and Feb. 10, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ACKERMANS, JOHN W. J. (M) experimental and sample body engineer, E. J. Thompson Co., *Pittsburgh,* (mail) 7309 Hamilton Avenue, Homewood.

BALL, GEORGE E. (S M) Headquarters 6th Corps, *Fort Sheridan, Ill.*

JONES, RICHARD L. (A) president, Auto Leather Mfg. Co., *Arlington, N. J.*

KROYER, J. M. (M) president, Kroyer Motors Co., P. O. Box 477, *Stockton, Cal.*

LAMBERT, G. F. (M) chief engineer, Kroyer Motors Co., *Stockton, Cal.*

MACCORMACK, J. G. (S M) assistant to the director of training, transportation corps, Motor Truck Division, *Washington,* (mail) 1825 Columbia Road.

NASH, CARLETON BIRTLEY (J) assistant engineer, Maccar Truck Co., *Scranton, Pa.,* (mail) 426 Colfax Avenue.

NEILL, GEORGE G. (A) Air Service, Washington.

NEWMANN, ARTHUR B. (M) tractor designer, Holt Mfg. Co., *Peoria, Ill.* (mail) 309 West Armstrong Avenue.

RAPP, ARTHUR H. (J) draftsman, Watson Products Corporation, *Canastota, N. Y.,* (mail) 133 West Chapel Street.

ROSE, HARRY (M) business manager, W. D. Block Motor Co., 200 State Street, *Grand Rapids, Mich.*

SHEELINE, PAUL D. (J) commercial engineer, A. D. Little, Inc., *Cambridge, Mass.,* (mail) 55 Magazine Street.

SIBLEY, B. E. (A) automotive engineer, lubrication department, Continental Oil Co., Denver, Col.

THOMPSON, JOHN F. (M) manager of technical department, International Nickel Co., 43 Exchange Place, *New York City.*

VANNEMAN, JOHN A. (M) engineer, Eisemann Magneto Corporation, *Brooklyn, N. Y.,* (mail) 1488 Union Street.

WATKIN, L. M. (A) Eastern sales manager, Standard Steel & Bearings, Inc., *Philadelphia,* (mail) 1017 Marlyn Road.

YOUNG, EARLE L. (A) factory manager, Laminated Shim Co., Inc., New York City, (mail) 1112 Park Avenue, *Hoboken, N. J.*

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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The Summer Meeting

THE 1921 Summer Meeting at West Baden promises to be the largest in the history of the Society if the number of responses to the first announcement is accepted as a criterion. One week after the mailing of the first folder over 150 members had forwarded their reservation blanks. This emphasizes the necessity of making early application for hotel accommodations if the better locations are desired.

The Society is unusually fortunate in having secured the acceptance of Sir Dugald Clerk, the noted British scientist, of an invitation to attend the Summer Meeting and address the members on the fundamental theories on which the internal-combustion engine is based. In 1878, long before the advent of the automobile, Sir Dugald Clerk presented papers disclosing the results of his study and development of the gas engine. He has since devoted his life to research work in the internal-combustion engineering field and is responsible for much of the thermodynamic theory which has formed the basis of our present-day engine design. His writings are well known and appreciated by all who have made a thorough study of the theory of the internal-combustion engine. Sir Dugald Clerk plans to review his research study from its earliest stage to the present time, emphasizing the several fundamental theories as they were developed and summarizing these in a manner that will make them of the greatest value to the engine designer. We feel sure that our members will appreciate the unusual importance of this paper, and we expect extraordinary interest to be shown in the discussion which will follow its presentation.

Technical Sessions and Recreation

Progress is being made in the arrangement of the various technical sessions which will be devoted to the topics of Research, Fuel, Aircraft, Farm Power, Highways, and Engineering as a Sales Stimulus. The question of bettering the efficiency of existing automotive engines to improve their economy will be treated at the Fuel Session. This important factor in the fuel problem is often underestimated because of the usual tendency to concentrate on future development and new designs. One paper will disclose an interesting research study toward the development of a high-compression oil engine for automotive purposes and the engineering reasons for its desirability. The basic economic reasons for the present position of commercial aviation in the United States are receiving the attention of one of the Aviation Session authors and the recommendations he will offer for a strengthening of aircraft as transportation media should serve to promote the future of this branch of aviation. The powerplant of the airplane of the future will be treated at this session and some rather unconventional departures in design and installation will be presented. Great interest has been shown in the work of certain universities in the tractor field and it is hoped that one contribution from this source will be submitted at the Farm Power Session. The rather basic problem of an economical operating speed for tractors still seems to be of great importance in the application of automotive equipment to the farm and its discussion will be continued. There will be only one paper on highways, it being the intent of the Society to keep its members informed of the progress in highway research in this manner at each of the national meetings. The complete program of papers will be published just as soon as it is definitely arranged.

The arrangement and supervision of the sports program are progressing under the direction of Howard A. Coffin, who was assigned this task by C. F. Scott, chairman of the Meetings Committee. The unusually adequate facilities for sports contests at West Baden will assure a most entertaining week and enable the members to demonstrate their ability in golf, tennis, baseball, bowling, track and field events, and trap shooting. Letters inviting subscriptions to the sports fund have been sent to the companies in the industry and several have already proved their interest in the success of this phase of the meeting. The list of sport events will be published early enough to allow the members to engage in a suitable amount of spring preparation and report in top form for participation in the various contests.

The impression seems to be prevalent among some of the automotive companies that the Society is planning an extensive exhibit of a commercial nature at the Summer Meeting. This is not the case. The past custom of running tests of a purely engineering character in connection with the technical sessions is to be continued. The tractor men are planning a series of tests similar to those at Ottawa Beach and other branches of automotive engineering will probably receive similar treatment. There is however no intention of accepting exhibits which are strongly commercial in their scope.

The attention of those who intend to see the 500-mile race at Indianapolis on Monday following the Society Meeting is directed to the arrangement whereby members can secure seats in a section especially reserved for the

Society by so stating when ordering tickets from the Indianapolis Speedway Co. These seats are $7 each, directly across from the pits and just beyond the finish line.

Transportation Arrangements

The Society has succeeded in securing concessions from the railroad authorities in the way of reduced fares for the Summer Meeting. Round-trip tickets will be sold to the members at a reduction of 25 per cent. Some of the territories covered by certain of the passenger or trunk line associations would not agree to a reduction plan, but fortunately the territories where the plan is effective contain a very large percentage of the membership. The Mid-Western automotive centers such as Detroit, Cleveland, Chicago, Toledo, Indianapolis, and Dayton are all included. The Eastern centers, New York City, Philadelphia, Washington, Rochester, Pittsburgh and Buffalo will be included in the Eastern area. The only Society Sections which are not included in the agreement are Minneapolis and Boston. The railroads in New England, the South and West would not grant the fare reductions but members in these territories can purchase tickets to a point in the reduced fare area and receive the benefit of the reduction from this point to West Baden and return.

Plans are being made to run a special train from the East which will enable the members in the New York, Philadelphia and Boston territories to leave Monday forenoon and arrive at West Baden Tuesday in time for the opening of the Standards Committee Meeting. Particulars of this train and a detailed explanation of the reduced fare plan will reach the members shortly in the second Summer Meeting folder.

Undoubtedly many of the members in the Mid-Western territory will consider driving to West Baden. Reports received by the Meetings Committee indicate that there are many fine roads leading into Indianapolis and thence to West Baden. A map of the more important routes is now being prepared and will be mailed to the members for their use in planning the trip by automobile.

Remember the dates, May 24-28; the place, West Baden, Ind.; the numerous professional and recreational attractions; and send in your application for rooms early.

MARCH COUNCIL MEETING

THE meeting of the Council held on March 15 was attended by President Beecroft, First Vice-President Horning, Second Vice-Presidents Bachman and VanBlerck, Councilors Pope and Davis, Dr. H. C. Dickinson of the Bureau of Standards, Chairman C. A. Adams of the Engineering Division of the National Research Council, Chairman Scott of the Meetings Committee, and Secretary Clarkson.

Membership

One hundred and thirty applications for membership and enrollment were approved, 2 for Service Member, 2 for Foreign Member, 40 for Member, 57 for Associate, 27 for Junior and 2 for Student Enrollment. C. A. Bennett, A. A. Remington and W. M. VanDeuser were transferred from Member to Foreign Member grade; Theodore Hoffman from Associate to Foreign Member; Matthew J. Farrell, A. Gilson, H. G. Rendall and Harry M. Rugg from Associate to Member; Arthur A. Bull, C. D. Hanscom, Harold T. Youngren, E. R. Godfrey from Junior to Member.

Standards Matters

The following appointments to membership on the Standards Committee were made with assignment as indicated:

G. J. Mead—Chairman Powerplant Subdivision of Aeronautic Division
H. E. Derr—Truck Division
W. H. Bassett—Non-Ferrous Metals Division
W. R. Webster—Non-Ferrous Metals Division
Samuel Tour—Non-Ferrous Metals Division
C. E. Jeffers—Frames Division
Victor Preston—Passenger Car Body Division
G. E. Goddard, Vice-Chairman—Passenger Car Body Division

The Passenger Car Division was established as a new division of the Standards Committee. The lack of a division with general jurisdiction such as that which the name of the new division indicates has been felt from time to time when prompt handling of various subjects coming before the Standards Committee appeared desirable. It is intended that the new Division shall handle some subjects jointly with other divisions.

In response to a demand from many members of the Society, it was decided to establish an Axle and Wheel Division to consider in due course standard suggestions that have arisen in connection with various unsprung structural chassis elements, not including tires and rims. It is expected that this division will have an important part in the further formulation of hub standards. The personnel of the division will be announced at an early date.

David Sternbergh was appointed as the representative of the Society on the Sectional Committee on Gears of the American Engineering Standards Committee.

With reference to the receipt of the Report of the Tellers of Society Letter Ballot on Adoption of Standards under date of March 14, it was decided to not include in the next set of new date sheets the recommendation of the Engine Division with regard to muffler sizes and mounting, in view of the fact that 18 negative votes were cast for specific reasons of weight against the recommendation.

Earle Buckingham was nominated in place of H. T. Herr as the representative of the Society on the National Screw Thread Commission.

Meetings

It was reported that the total net expense of the 1921 Winter Meeting of the Society was $4,466.63. The corresponding figure for the 1920 Annual Meeting was $6,896.11.

Chairman Scott of the Meetings Committee reported that his committee feels that the success of the Semi-Annual Meeting of the Society to be held at West Baden May 24 to 28, was already assured so far as attendance and professional value are concerned.

Research

The plans under consideration following the establishment of the Research Department of the Society, were discussed comprehensively at the Council dinner in the evening. In addition to the Society officers who participated in the sessions held during the day, there were in attendance Past-Presidents Riker and Manly, Prof. R. M. Anderson of Stevens Institute of Technology, Prof. E. H. Lockwood of Yale University, Prof. G. B. Upton of Cornell University, Prof. C. A. Adams of Harvard University, C. B. Veal and Herbert Chase. Unanimous approval was expressed of the program that has been formulated in a general way for the collection, study, collation and dissemination of fundamental engineering knowledge of special importance to the automotive industry currently. Very gratifying assurance was had of assistance and cooperation from the universities represented at the dinner.

Automobile Exhaust Gases and Vehicular-Tunnel Ventilation[1]

By A. C. Fieldner,[2] A. A. Straub[3] and G. W. Jones[4]

Annual Meeting Paper — *Illustrated with* Photograph and Charts

THE data given in this paper were obtained in the course of an investigation undertaken by the Bureau of Mines in cooperation with the New York and New Jersey State Bridge and Tunnel Commissions to determine the average amount and composition of the exhaust gases from motor vehicles under operating conditions similar to those that will prevail in the Hudson River Vehicular Tunnel. A comprehensive set of road tests upon 101 motor vehicles including representative types of passenger cars and trucks was conducted at the Pittsburgh Experiment Station of the Bureau of Mines in accordance with a program suggested by C. M. Holland, chief engineer of the tunnel commission.

The tests were started on Dec. 1, 1919, and were completed on Sept. 30, 1920, thus covering both winter and summer operating conditions. The cars tested were taken at random from those offered by private individuals, corporations and automobile dealers of Pittsburgh, and the tests were made without any change in carbureter or other adjustment. The results can therefore be taken as representative of motor vehicles as they are actually being operated on the streets at the various speeds and grades that will prevail in the tunnel. Furthermore, the information obtained in this investigation can be applied also to ventilation problems of other vehicular tunnels and subways, several of which are under construction or are proposed in other cities of the United States.

The motor vehicles tested comprised 101 automobiles and trucks of six representative classes as given in Table 1.

TABLE 1—CLASSES OF MOTOR VEHICLES TESTED

Class	Description	Number of cars tested
1	Five-passenger cars	19
2	Seven-passenger cars	13
3	Trucks up to 1½ tons	12
4	Trucks from 1½ to 3 tons inclusive	22
5	Trucks from 3½ to 4½ tons inclusive	17
6	Trucks of 5 tons and over	18
	Total	101

Twenty-four cars were tested under winter conditions between Dec. 1, 1919 and Feb. 6, 1920; and 77 cars were tested under spring and summer conditions between March 11 and Sept. 30, 1920.

Test Conditions and Methods

In the winter series, all cars were tested under the following conditions:

(1) Car standing and the engine racing
(2) Car standing and the engine idling
(3) Car accelerating from rest to 15 m.p.h. up a 3 per cent grade
(4) Car running 15, 10 and 3 m.p.h. up a 3 per cent grade
(5) Car running 15, 10 and 3 m.p.h. down a 3 per cent grade
(6) Car accelerating from rest to 15 m.p.h. on a level grade
(7) Car running 15, 10 and 3 m.p.h. on a level grade

Fig. 1—Two and One-Half-Ton Truck Equipped with Gasoline Measuring Apparatus and the Exhaust Gas Sampling Tube Which Were Used in Connection with the Tests

In the summer series the general test conditions were simplified by omitting the racing, idling and accelerating tests in most cases as sufficient data were obtained in the winter tests to show that these particular test conditions were of minor importance in estimating the total quantity of carbon monoxide generated in the tunnel. A 6-m.p.h. test was substituted for the 3-m.p.h. test as being more representative of slow-moving traffic and a 20-m.p.h. test on a level grade was added for passenger cars. The remaining tests were the same as in the winter series. Most of the heavy trucks were tested at 6 and 10 m.p.h. only, as they could not be speeded to 15 m.p.h.

The trucks and the seven-passenger cars were tested with full load at their rated capacity and also with no load other than the two observers, chauffeur and apparatus weighing 50 lb. The five-passenger cars were tested with the light load only, consisting of three men and the apparatus.

All cars were tested in the same condition as received, without any change in carbureter or other adjustment, and with the same brand of gasoline as was being used in the car. Fig. 1 shows a 2½-ton truck equipped with gasoline measuring apparatus located in front of driver's seat and the exhaust gas sampling tube which can be seen back of cab ready for test.

The gasoline measuring apparatus shown in Fig. 2

[1] Published with the permission of the Director of the Bureau of Mines and the Chief Engineer of the New York and New Jersey State Bridge and Tunnel Commission.

[2] Supervising chemist, Bureau of Mines Experiment Station, Pittsburgh.

[3] Mechanical engineer, Bureau of Mines Experiment Station, Pittsburgh.

[4] Assistant physical chemist, Bureau of Mines Experiment Station, Pittsburgh.

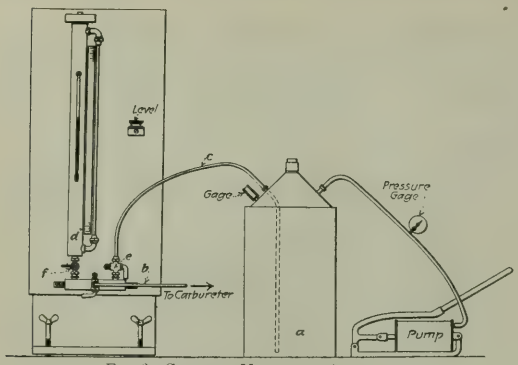


FIG. 2—GASOLINE MEASURING APPARATUS

was connected directly to the carbureter and to a reserve supply of gasoline *a*, through the copper pipes *b* and *c*, respectively. As the car crossed the boundary lines of the test course at the predetermined speed for the test the gasoline feed was switched from the reserve supply to the measuring tube *d* by closing the cock *e* and opening *b*. At the end of the test course, a reverse operation of these cocks switched the supply back to the reserve supply tank.

The exhaust gas sampling apparatus is shown in Fig. 3. A ¼-in. copper tube, *g*, bent at right angles, with the opening turned toward the engine was introduced into the exhaust pipe between the engine and muffler. The exhaust gas pressure was sufficient to maintain a rapid stream of gas through the heavy-walled rubber tube, *h*, connected to the glass tee, *i*, on the sampler board. The main stream of exhaust gases passed on through the rubber tube, *h*, and was discharged into the atmosphere through the water seal, *j*, thus preventing any air from being sucked back into the sample.

The exhaust gas sample was collected continuously at a uniform rate over the whole period of the test, in a 250-cc. glass sampling tube connected to the downward branch of the tee, *i*. One observer gave his entire attention to regulating the flow of a 5 per cent solution of sodium chloride previously saturated with exhaust gas from the sample tube, by adjusting the screw clamp at the lower end of the tube.

The samples were analyzed in duplicate for carbon dioxide, oxygen, carbon monoxide, hydrogen and methane on a laboratory type Burrell-Orsat apparatus[5] as used in the Bureau of Mines for a complete gas analysis. The carbon dioxide was absorbed in a potassium hydroxide solution, the oxygen in potassium pyrogallate, the carbon monoxide in two bubbling pipettes in series containing an acid cuprous chloride solution and the hydrogen, methane and any residual carbon monoxide were determined by slow combustion in the presence of a hot platinum wire.

In this method of analysis any gasoline vapor and other hydrocarbons appear as methane. In other words, the analysis gives the equivalent methane value for all the hydrocarbons in the exhaust gas, and the result is correct as regards the carbon content for computing the total volume of exhaust gases from the gasoline consumption and the carbon content of the gasoline. This relation was checked to within 6 per cent by actual measurement of exhaust gas into a 50-cu. ft. container.

The determination of the gasoline vapor as methane causes the hydrogen value in the analysis to be somewhat less than its true value. This error in the hydrogen value has no effect on the calculation of the true value of the carbon monoxide, carbon dioxide and methane equivalent of the total hydrocarbons.

All the streets in the 3-per cent grade course, Fig. 4, were paved with asphalt and in excellent condition. While there was a fair amount of traffic, no trouble was experienced from stoppage by other vehicles due to the absence of much traffic on the few intersecting streets.

The Stanton Avenue portion of the level course, Fig. 5, outside of Highland Park was asphalt in good condition; the remainder of the course in the Park was macadam in rather bad condition. There were no deep holes, but the surface was worn and uneven.

[5] See Bureau of Mines Bulletin No. 42 entitled The Sampling and Examination of Mine Gases and Natural Gas by G. A. Burrell and F. M. Seibert, p. 43.

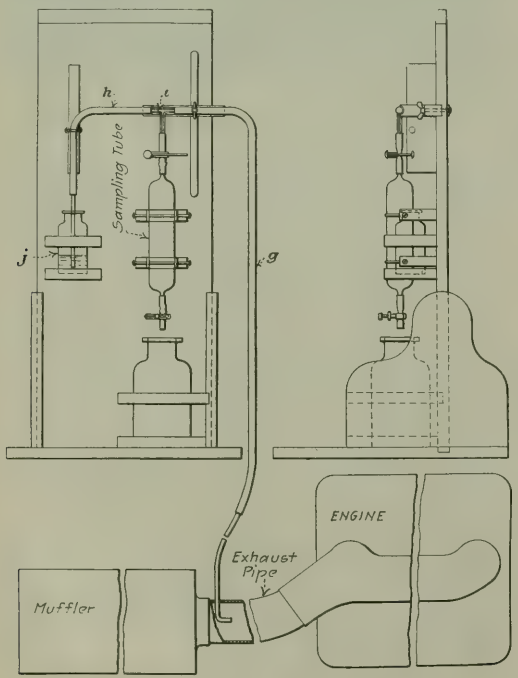


FIG. 3—EXHAUST GAS SAMPLING APPARATUS

METHODS OF COMPUTING RESULTS

The total volume of exhaust gases produced per gallon of gasoline consumed was computed from the analysis of the exhaust gases and the weight and analysis of the gasoline. This computation is based on the assumption that all the carbon in the gasoline appears in the exhaust gases. As a matter of fact, there is a small error due to solid particles of carbon in the exhaust and on the engine surfaces and the leakage of gasoline into the crankcase. This error can be partly compensated for or even exceeded in some cases by lubricating oil burning in the cylinders. The total error is probably negligible. Some tests were made with the engine idling, the exhaust gases being collected and measured in a 50-cu. ft. calibrated gas tank. The measured volumes checked to

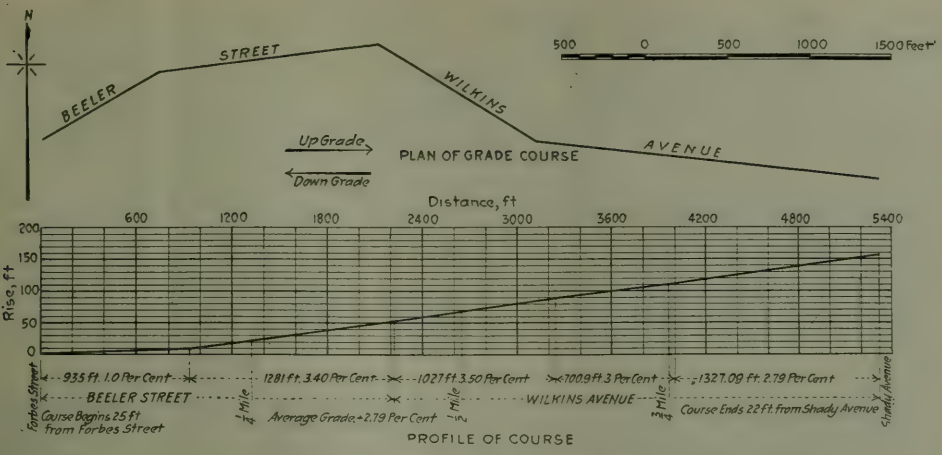


FIG. 4—PLAN AND PROFILE OF THE 3-PER CENT GRADE COURSE

within 6 per cent of the volume computed from the analysis in the usual manner.

The volume of exhaust gases was computed by the following method:

From Gasoline Analysis

where

a = The specific gravity of the gasoline at 60 deg. fahr.
b = The percentage of carbon in the gasoline
8.33 = The weight of 1 gal. of water at 60 deg. fahr., lb.
$8.33ab$ = Lb. of carbon in 1 gal. of gasoline (1)

From Gas Analysis

where

c = The percentage of carbon dioxide, by volume, in the exhaust
d = The percentage of carbon monoxide, by volume, in the exhaust
e = The percentage of methane, by volume, in the exhaust
0.1158 = The weight of 1 cu. ft. of carbon dioxide at 65 deg. fahr. and 29.92 in. of mercury, lb.
0.0732 = The weight of 1 cu. ft. of carbon monoxide at 65 deg. fahr. and 29.92 in. of mercury, lb.
0.0420 = The weight of 1 cu. ft. of methane at 65 deg. fahr. and 29.92 in. of mercury, lb.
$0.1158 \times 0.272^c = 0.0316$ = lb. of carbon in 1 cu. ft. of carbon dioxide at 65 deg. fahr. and 29.92 in. of mercury
$0.0732 \times 0.429^c = 0.0314$ = lb. of carbon in 1 cu. ft. of carbon monoxide at 65 deg. fahr. and 29.92 in. of mercury
$0.0420 \times 0.75^c = 0.0315$ = lb. of carbon in 1 cu. ft. of methane at 65 deg. fahr. and 29.92 in. of mercury
$0.0316c \times 0.0314d \times 0.0315e$ = Total pounds of carbon in 1 cu. ft. of exhaust gas

This expression may be simplified by using the mean value 0.0315 as follows:

$0.0315\ (c + d + e)$ = Total pounds of carbon in 1 cu. ft. of exhaust gas ((2)

Dividing (1) by (2)

$8.33ab/0.0315\ (c + d + e) = 264.4ab/(c + d + e)$ = The number of cubic feet of exhaust gas per gallon of gasoline at 65 deg. fahr. and 29.92 in. of mercury

The numerator of the above expression is constant for each gasoline and represents the total cubic feet of car-

[c] Ratio of the atomic weight of carbon to the molecular weight of the gas.

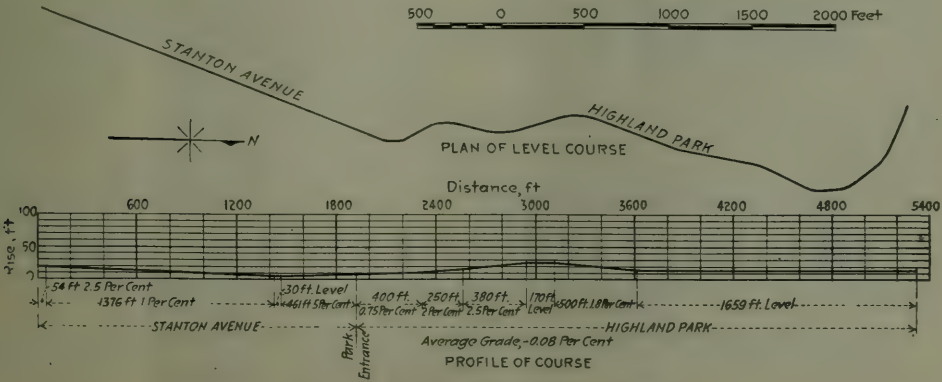


FIG. 5—PLAN AND PROFILE OF THE LEVEL COURSE

TABLE 2—ANALYSES OF GASOLINE USED IN TESTS

Kind	Sample Number	Specific Gravity at 60 Deg. Fahr.	Baumé Gravity at 60 Deg. Fahr.	Unsaturation, per cent	Distillation in 100-cc. Engler Flask, Temperature in Deg. Fahr.						Ultimate Analysis	
					First Drop	Per Cent 20	Per Cent 50	Per Cent 90	Dry Point	Average	Carbon, per cent	Hydrogen, per cent
A	1	0.713	66.4	2.5	88	151	225	381	441	239	84.3	15.7
A	9	0.710	67.2	...	84	149	234	385	421	241	84.4	15.4
AM	2	0.731	61.5	...	93	181	266	394	451	282	84.3	15.7
AM	3	0.743	59.2	1.5	95	192	271	405	457	275	84.5	14.5
AM	10	0.748	57.2	...	86	219	277	392	435	278	84.5	15.2
G	4	0.730	61.8	2.0	104	187	259	363	414	259	85.2	14.8
G	8	0.736	60.2	...	115	194	241	352	419	253	85.1	14.7
G	11	0.747	57.4	2.0	122	219	262	374	433	275	84.9	15.3
M	5	0.722	63.9	3.0	84	167	284	432	448	277	85.3	14.7
MM	6	0.742	58.7	2.5	80	201	302	432	448	289	86.0	14.0
B	7	0.796	45.9	2.0	115	199	248	381	430	264	88.3	11.7

bon containing gases, carbon dioxide, carbon monoxide and methane, that is produced by a gasoline of the given specific gravity and carbon content. The denominator varies with each test and represents the proportion by volume of carbon containing gases in 1 cu. ft. of the exhaust gas.

All cars were tested with the same brand of gasoline as was being used in the car at the time it was submitted for test. To avoid analyzing a large number of samples of the same brand, a large stock of each of the brands in use around Pittsburgh was obtained and carefully sampled and complete analyses of each sample are given in Table 2. The ultimate analyses, giving carbon and hydrogen content, were made by W. A. Selvig, analytical chemist of the Bureau of Mines, and the standard distillation tests and specific gravity determinations were made in the Bureau's petroleum laboratory under the direction of E. W. Dean, petroleum chemist.

RESULTS OF TESTS

It is not possible to give the results of the individual tests of each of the 101 cars included in the entire investigation within the limited scope of this article. Complete results and full details will be published in a bulletin by the Bureau of Mines and a more extensive summary will be included in a forthcoming report of the Chief Engineer of the New York and New Jersey State Bridge and Tunnel Commissions. The present paper will therefore be confined to a presentation of the average exhaust gas analyses, gasoline consumption and the quantity of carbon monoxide produced and a discussion of the application of this data to the ventilation of vehicular tunnels and present day economy in the use of gasoline.

Figs. 6, 7, and 8 give a graphical summary of the average percentage of carbon monoxide in the exhaust gas, the gasoline consumption and the cubic feet of carbon monoxide per hour for each class of motor vehicles under the various test conditions. The volume of carbon monoxide emitted is the important figure in the problem of ventilation, as this gas is the poisonous constituent of the exhaust gases that must be diluted with air so that its concentration in the tunnel atmosphere will at no time exceed 4 parts in 10,000 parts of air.

All the results shown in the curves, except those for five-passenger cars which were tested with an average load only consisting of three men and the apparatus, are averages of two tests, one with no load other than the chauffeur, two observers and 50 lb. of apparatus and the other with a load of full-rated capacity. Figs. 6 and 7 cover winter and summer tests respectively for passenger cars and light-speed trucks. All the heavy trucks were tested in the spring and summer and are shown in Fig. 8.

It will be noticed from the plotted results that the average percentage of carbon monoxide for each class of vehicles varies between 5 per cent as the minimum and 9 per cent as a maximum, except in the heavy truck class where the variation is between 4 and 8 per cent, the range of variation being the same. The larger percentages tend to be produced when the engine is racing, idling or running on light load on the low gear at 3 m.p.h., and on the low-speed level grade tests for summer conditions. However, the greatest amount of carbon dioxide per hour is generated under conditions of greatest load, when accelerating or running up grade at the highest speed. The relative quantity of carbon monoxide produced depends primarily on the gasoline consumption as shown at a glance by the similar rise and

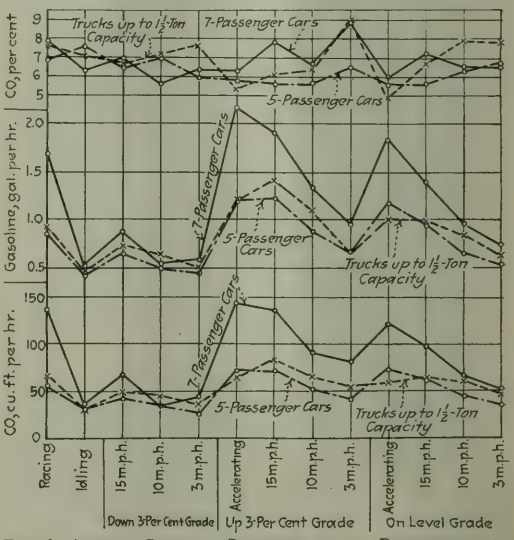


FIG. 6—AVERAGE GASOLINE CONSUMPTION AND PERCENTAGE AND QUANTITY OF CARBON MONOXIDE FOR PASSENGER CARS AND TRUCKS UNDER 1½-TONS CAPACITY TESTED UNDER WINTER CONDITIONS

fall of the "gasoline" and "cubic feet of carbon monoxide" curves.

The average percentage of carbon monoxide under all conditions of test for each class of vehicles was, five-passenger cars 6.5; seven-passenger cars 7.2; trucks up to 1½ tons capacity 6.9; trucks from 1½ to 3 tons inclusive, 6.3; trucks from 3½ to 4½ tons inclusive, 6.9; trucks of 5 tons and over, 6.4. The average percentages

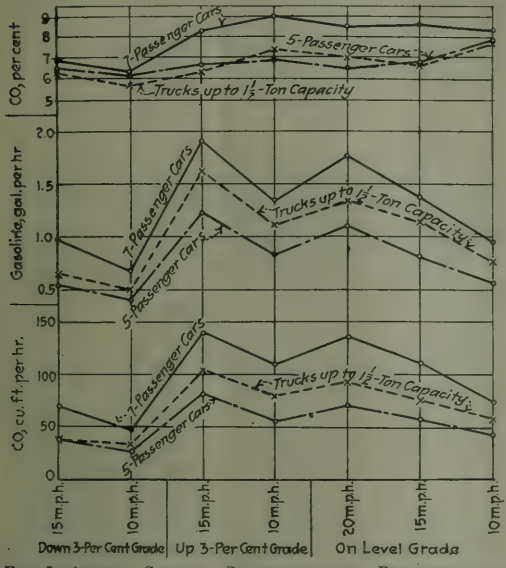


FIG. 7—AVERAGE GASOLINE CONSUMPTION AND PERCENTAGE AND QUANTITY OF CARBON MONOXIDE FOR PASSENGER CARS AND TRUCKS UNDER 1½-TONS CAPACITY TESTED UNDER SUMMER CONDITIONS

of carbon monoxide obtained on these tests is practically the same as those obtained by Hood, Kudlich and Burrell[7] in tests of gasoline mine locomotives with carbureters adjusted for the maximum power. They found that when the maximum power was being developed the gases usually contained from 5 to 7 per cent carbon monoxide, and that the carbon monoxide content could be

[7] See Bureau of Mines Bulletin No. 74 entitled Gasoline Mine Locomotives in Relation to Safety and Health by O. P. Hood, R. H. Kudlich and G. A. Burrell, pp. 66 to 68.

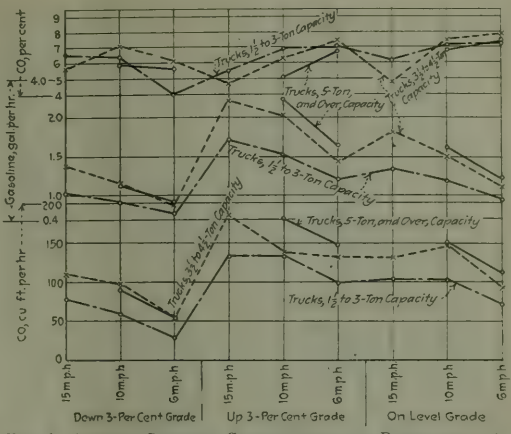


FIG. 8—AVERAGE GASOLINE CONSUMPTION AND PERCENTAGE AND QUANTITY OF CARBON MONOXIDE FOR TRUCKS OVER 1½-TONS CAPACITY TESTED UNDER SUMMER CONDITIONS

increased to as much as 9 per cent without reducing the power appreciably.

These investigators have also shown that the proportion of carbon monoxide in exhaust gases varies from zero to about 14 per cent, the amount depending on a number of variables, chief of which are

(1) Ratio of air to gasoline
(2) Completeness of the vaporization and mixing
(3) Speed of the engines
(4) Temperature of the air and the jacket water
(5) Quality and time of the spark
(6) Degree of compression
(7) Quality of the gasoline or other fuel

In view of this large number of variables it is not surprising that extremely large variations in exhaust gas composition were obtained in testing motor vehicles taken from ordinary service without any adjustment prior to the test. This is particularly true since they were driven in a variable manner with foot accelerator or hand throttle by different drivers over an approximately smooth course, yet one with some rough places requiring opening and closing of the throttle to maintain a constant speed.

It is, therefore, not possible to draw conclusions on the effect on exhaust gas composition of the various factors

TABLE 3—BEST AND POOREST RESULTS OBTAINED ON SEVERAL REPRESENTATIVE MAKES OF LOADED PASSENGER CARS AND TRUCKS

Car No.	Make of Car	Type of Vehicle	Speed on Level Grade, m.p.h	Miles per gal.	Increase in Mileage, per cent.	Completeness of Combustion, per cent.	Exhaust Gas Analyses by Volume, Per Cent					Air-Gasoline Ratio, lb.
							Carbon Dioxide	Oxygen	Carbon Monoxide	Methane	Hydrogen	
1	C	Five-passenger car	15	27.30	105.8	100	13.0	2.6	0.0	0.0	0.0	16.7
9	C	Five-passenger car	15	13.26	.....	84	11.8	0.8	3.7	0.3	1.6	13.5
11	G	Seven-passenger car	15	18.61	66.8	93	9.3	5.4	1.3	0.0	0.1	20.1
10	G	Seven-passenger car	15	11.16	.....	61	7.5	2.1	9.3	1.4	4.0	10.7
84	X	¾-ton truck	15	15.39	44.5	90	10.7	3.9	1.7	0.5	0.2	16.6
76	X	¾-ton truck	15	10.66	.....	59	7.1	0.7	10.7	1.0	5.1	10.3
38	Y	3½-ton truck	10	6.55	36.2	87	12.9	0.3	1.9	0.8	0.4	13.9
57	Y	3½-ton truck	10	4.81	.....	65	7.5	0.8	10.6	1.0	4.9	10.2
44	D	Five-passenger car	15	10.26	.....	49	5.3	1.0	13.2	1.9	7.1	9.0

TABLE 4—EFFECT OF CARBURETER ADJUSTMENT ON GASOLINE CONSUMPTION AND EXHAUST GAS ANALYSIS

Carbureter Adjustment, Needle Valve Turns	Gasoline Consumption		Exhaust Gas Analysis, Per Cent						Air per pound of gasoline, lb.	Completeness of Combustion, per cent	Remarks
	Gallons per mile	Miles per gal	Carbon Dioxide	Oxygen	Carbon Monoxide	Methane	Hydrogen	Nitrogen			
1	0.0670	14.9	13.4	1.7	1.2	0.2	0.0	83.5	14.5	95	[8]
1¼	0.0720	13.9	12.0	1.4	2.0	1.1	0.0	83.5	14.2	85	[9]
1 7/16	0.0940	10.6	10.2	0.3	6.4	0.8	2.4	79.9	11.8	74	[10]
1¾	0.1142	8.8	6.5	1.2	11.6	1.0	6.4	73.3	9.9	56	[11]

[8] Exhaust clear; mixture too lean to operate without the use of the air choke.

[9] Exhaust clear; operation satisfactory. Air choke one-quarter on during part of the test.

[10] Exhaust slightly smoky; operation satisfactory. Car had good "pick-up."

[11] Smoky exhaust; mixture seemed too rich for satisfactory operation.

just enumerated, except with regard to the ratio of air to gasoline or the carbureter adjustment.

A study of all the tests made shows that the variation in exhaust gas composition due to carbureter adjustment is far greater than any other factor. They do not throw much light on the advantage of any particular make or type of carbureter, nor should any conclusions be drawn as to the merits or demerits of any particular make of car. Table 3 gives a comparison of the best and poorest tests obtained on several well-known makes of passenger cars and trucks. Car No. 1 had the best gas analysis, and greatest mileage of any car tested. Car No. 44, also a five-passenger vehicle, had the poorest gas analysis and the lowest mileage in its class. Both cars operated without any apparent difficulty throughout the tests. Car No. 11 did not operate smoothly and lacked flexibility at low speeds due to the mixture being too lean. However, the mileage per gallon of gasoline was much higher than with the other cars in the same class. At speeds above 15 m.p.h. it operated smoothly and gave a good illustration of the tremendous quantity of fuel that can be saved by using lean mixtures. It should be noted that in each case the car with the leaner mixture shows the largest mileage per gallon of gasoline. The increase in mileage ranges from 36 to 106 per cent.

The effect of various carbureter adjustments on an individual car is shown in Table 4. Before putting this car through the standard series of road tests the driver, an automobile mechanic, was asked to place the carbureter in good adjustment. He set it after the engine was warmed up to running conditions, at 1 7/16 turns of the needle valve. As shown in the table this setting produced 6.4 per cent carbon monoxide and 10.2 per cent carbon dioxide, a little better than the average analysis of all the cars tested. Tests were then repeated under identical conditions with both richer and leaner settings. It was found that 1¼ turns of the carbureter needle gave 12 per cent carbon dioxide and 2 per cent carbon monoxide and 31 per cent greater mileage; also the car operated satisfactorily. This car was a roadster with a four-cylinder engine having a bore of 4⅛ in. and a 4½-in. stroke. A Johnson carbureter was used and the intake air and the manifold were heated. The gasoline burned had a Baumé gravity of 66.4 deg. and a distillation of 10 per cent at 127 deg. fahr., 50 per cent at 225 deg. fahr. and a dry point of 441 deg. fahr, or an average of 239 deg. fahr. The tests were run on an asphalt pavement in good condition ascending a 3-per cent grade at 15 m.p.h.

This test is typical of the great majority of the passenger cars and trucks tested. The carbureters were invariably adjusted on the rich side for the greatest flexibility of operation rather than for the maximum economy of gasoline. One pound of ordinary fuel gasoline of today such as was used in the tests just described requires approximately 15 lb. of air for complete combustion. The maximum thermal efficiency is obtained at about 16 lb.[12] of air to 1 lb. of gasoline and the maximum power with 12 to 13 lb. of air.[13] Herein lies the reason for the use of rich mixtures. The average driver demands first of all power and flexibility of operation. He sets his carbureter adjustment rich enough to give good operation with a cold engine and for slow driving in heavy traffic, with plenty of reserve power for hill climbing and bad roads. If he errs somewhat on the rich side it does not become manifest in the loss of power, but only in the increased gasoline consumption which in many instances does not concern him at all. An inspection of the average thermal efficiency and power curves of Fig. 9 shows that the pro-

[12] With this mixture the engine develops about 85 per cent of its maximum power.

[13] See THE JOURNAL, November, 1919, p. 364.

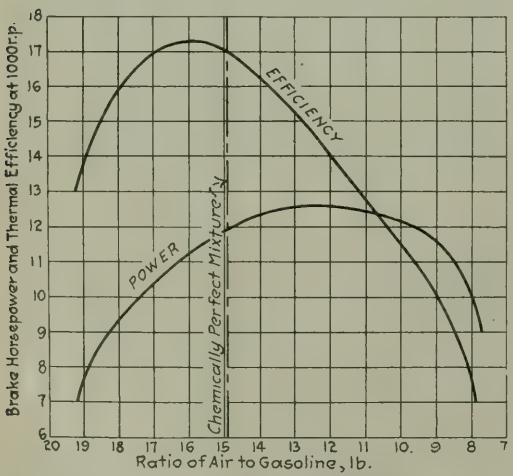


FIG. 9—CURVES SHOWING THE RELATION OF THE AIR-GASOLINE RATIO TO THE POWER AND THERMAL EFFICIENCY OF A FOUR-CYLINDER ENGINE OPERATING AT 1000 R.P.M.

portion of air in the mixture can be reduced to 9 lb. of air to 1 lb. of gasoline with a loss of only 9 per cent in power, although the economy and the efficiency are tremendously reduced.

Fig. 10 shows the relation between the air-gasoline ratios and the percentage of carbon monoxide in the exhaust gas for 23 passenger cars and trucks, the average of light and full-load tests, tested under winter conditions at 15 m.p.h. running up a 3 per cent. grade. Fig. 11 covers 20 passenger cars and trucks tested under the same conditions in the summer; and Fig. 12 shows the same relation for 54 trucks of from 1½ to 5 tons capacity and over, tested in the summer at 10 m.p.h. up a 3 per cent grade.

The air-gasoline ratios varied from 15.8 with about 0.5 per cent of carbon monoxide, to 9.0 with 13.0 per cent of carbon monoxide. The average air-gasoline ratio was 12.3 with an average carbon monoxide percentage of 6.4, practically the exact figure for maximum power. Obviously, carbureters are adjusted in practice for maximum power and not for maximum thermal efficiency and economy of gasoline.

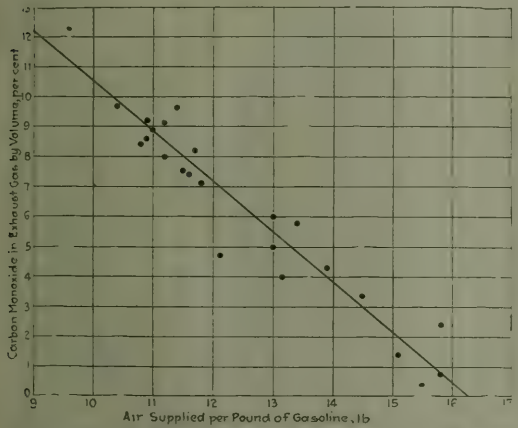


Fig. 10—Average Relation Between Percentage of Carbon Monoxide and Air-Gasoline Ratio for Passenger Cars and Light Trucks Tested under Winter Conditions up a 3-Per Cent Grade

The results for the 54 trucks plotted in Fig. 12 show most strikingly the lack of attention paid to economical carbureter adjustment; the air-gasoline ratios are uniformly distributed over the entire range of mixtures on which it is possible to operate the engines.

The average loss of gasoline due to the continuous operation of a car at the point of maximum power is shown in Table 5, which gives computations from average exhaust gas analyses, heat in the gasoline and heat in the unburned exhaust gas constituents.

The completeness of combustion can also be calculated with sufficient accuracy directly by weight from the exhaust gas and by volume from the gasoline analyses as follows:

In making the calculation from the gasoline analysis if we let *A* designate the ratio of water vapor to carbon dioxide by volume on complete combustion which is equal to one-half the percentage of hydrogen divided by one-twelfth the percentage of carbon and assume the heat of combustion of carbon and hydrogen as 14,540 and 62,000 B.t.u. respectively, then the percentage of heat units due to carbon or *B* equals the percentage of carbon multiplied by 14,540 and divided by the sum of 14,540 times the percentage of carbon plus 62,000 times the percentage of hydrogen. Similarly the percentage of heat units due to hydrogen or *C* equals 62,000 times the percentage of hydrogen divided by the sum of 14,540 times the percentage of carbon plus 62,000 times the percentage of hydrogen.

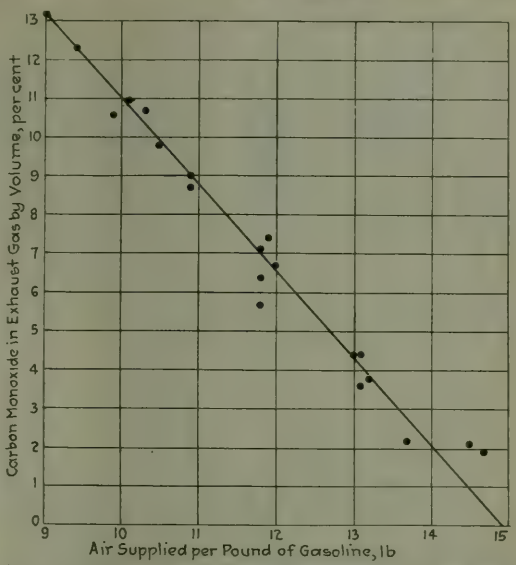


Fig. 11—Average Relation Between Percentage of Carbon Monoxide and Air-Gasoline Ratio for Passenger Cars and Light Trucks Tested under Summer Conditions up a 5-Per Cent Grade

In using the gas analysis if we designate the volume of carbon dioxide formed on complete combustion which is the sum of the percentages of carbon dioxide, carbon

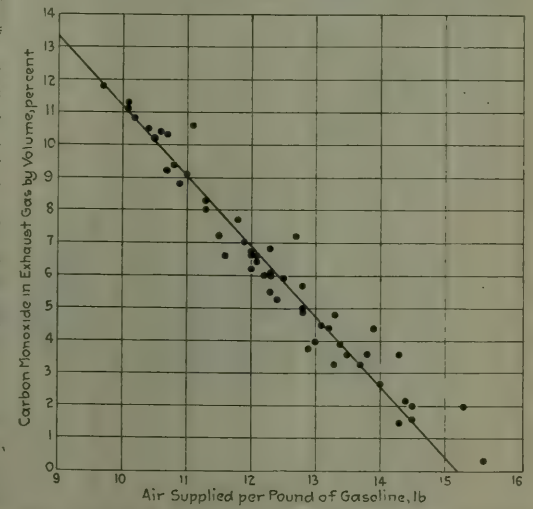


Fig. 12—Average Relation Between Percentage of Carbon Monoxide and Air-Gasoline Ratio for Trucks Over 1½ Tons Tested under Summer Conditions up a 3-Per Cent Grade

monoxide and methane by D and the completeness of the combustion of carbon which is the sum of the percentage of carbon dioxide plus three-tenths of the percentage of carbon monoxide divided by the sum of the percentages of carbon dioxide, carbon monoxide and methane by E, then the equivalent volume of water vapor formed on complete combustion equals the product of D multiplied by A. Likewise the completeness of the combustion of hydrogen or F equals unity minus the quotient of the sum of the percentage of hydrogen plus twice the percentage of methane divided by D times A. Hence the completeness of the combustion of the gasoline equals

$$(B \times E) + (C + F)$$

The factors A, B and C are practically constant for any given grade of gasoline. For gasolines used in these tests these factors averaged as follows:

Grade of Gasoline	Factors A	B	C
68-70	1.09	57	43
Motor	1.04	58	42
Benzol Mixtures	0.80	64	36

TABLE 5—AVERAGE COMPOSITION OF EXHAUST GAS, BY VOLUME, FROM TESTS OF 23 CARS, AT 15 M.P H.

	Level grade, per cent	Ascending 3 per cent grade, per cent
Carbon dioxide	8.9	9.6
Oxygen	2.3	1.3
Carbon monoxide	6.3	6.4
Methane	0.9	0.6
Hydrogen	3.0	2.9
Nitrogen	78.6	79.2
Total	100	100
Cubic feet of exhaust gases at 65 deg. fahr. and 29.92 in. of mercury	988	

Composition of Gasoline

Specific gravity	0.713
Carbon, per cent	84.3
Hydrogen, per cent	15.7
Calorific value, B.t.u. per lb.	21,300
B.t.u. per gal.	130,000

[14] Gross British thermal units per cubic foot at 65 deg. fahr. and 29.92 in. of mercury.

[15] See *The Automobile*, vol. 30, pp. 395 and 442.

[16] See the *Proceedings of the Institution of Automobile Engineers*, vol. 3, p. 293.

The exhaust gas from 1 gal. of gasoline on level-grade tests contains

$988 \times 6.3 = 62.2$ cu. ft. of carbon monoxide
$988 \times 0.9 = 8.9$ cu. ft. of methane
$988 \times 3.0 = 29.6$ cu. ft. of hydrogen

The total heat in the unburned gases per gallon of gasoline is

$62.2 \times 320^{14} = 19{,}900$ B.t.u.
$8.9 \times 1{,}000 = 8{,}900$ B.t.u.
$29.6 \times 322 = 9{,}600$ B.t.u.

38,400 B.t.u.

$38{,}400 \div 130{,}000 = 29.5$ per cent

Hence 29.5 per cent of the total heat of the gasoline goes out in the exhaust in the form of combustible gases, or in other words, the completeness of combustion is $100 - 29.5 = 70.5$.

Average Composition of Exhaust Gas and Completeness of Combustion

The average percentage of unburned gases found in the exhaust of the various classes of motor vehicles tested was materially higher than was expected in view of the results of somewhat similar although much less extensive road tests reported by previous investigators. Herbert Chase[15] reported in 1914 road tests on 12 passenger cars which showed only one-third of the percentage of carbon monoxide found in the Bureau of Mines tests, although the percentages of carbon dioxide were nearly the same. A comparison of these results are given in Table 6. Ballantyne[16] also states that

> As the result of very numerous analyses of exhaust gases from a great variety of passenger cars, I found that the percentage of carbon monoxide ranged in 1907 from a maximum of 10.3 to a minimum of 0, with an average of 3.5, while in 1908 the maximum was 8.9, the minimum 1.0, and the average 2.7 per cent. It is not too much to say that a gasoline fed car should in respect to the emission of carbon monoxide, be hardly a worse offender than a modern locomotive, the products of combustion of which according to the very full investigation of Brislee, contain in first-class locomotive practice from 0 to 4.2 per cent of carbon monoxide with an average of 1 per cent.

In the Pittsburgh tests only eight out of 44 passenger cars and light trucks showed 3.5 per cent or less of

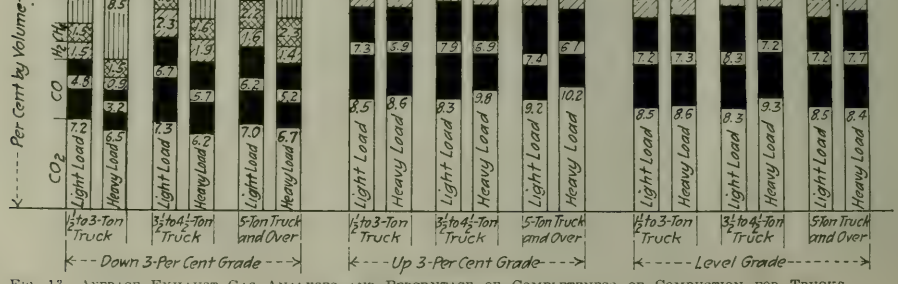

Completeness of Combustion, per cent
68 70 62 62 61 59 70 72 69 72 68 73 68 68 66 70 65 66
Per Cent by Volume
O2
CO
CO2
Light Load
Heavy Load
½ to 3-Ton Truck
3½ to 4½-Ton Truck
5-Ton Truck and Over
Down 3-Per Cent Grade
Up 3-Per Cent Grade
Level Grade

FIG. 13—AVERAGE EXHAUST GAS ANALYSES AND PERCENTAGE OF COMPLETENESS OF COMBUSTION FOR TRUCKS OPERATING AT 6 M. P. H.

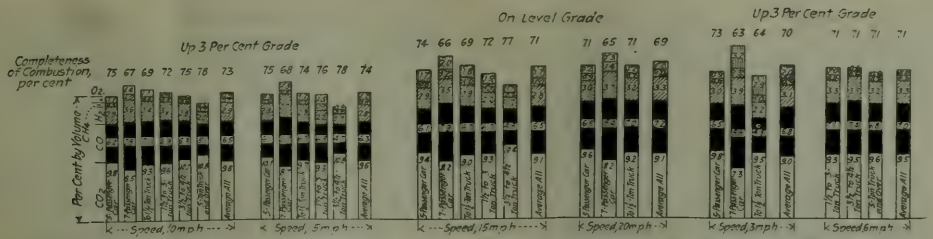

Completeness of Combustion, per cent
Per Cent by Volume
O2
CO
CO2
Up 3 Per Cent Grade
On Level Grade
Up 3 Per Cent Grade
75 67 69 72 75 78 73
75 68 74 76 78 74
74 66 69 72 77 71
71 65 71 69
73 63 64 70
71 71 71 71
5 Passenger Car
7 Passenger Car
1 Ton Truck
2 to 3 Ton Truck
3 to 5 Ton Truck
Average All
Speed, 10 m p h
Speed, 5 m p h
Speed, 15 m p h
Speed, 20 m p h
Speed, 3 m p h
Speed, 6 m p h

FIG. 14—AVERAGE LIGHT AND FULL-LOAD EXHAUST GAS ANALYSES AND PERCENTAGE OF COMPLETENESS OF COMBUSTION FOR CARS AND TRUCKS OPERATING ON DIFFERENT GRADES AT VARIOUS SPEEDS

carbon monoxide, and the average was 6.5 to 7.0 per cent of carbon monoxide for tests under approximately the same conditions. Undoubtedly the automobile of today has become a much worse offender on the score of discharging carbon monoxide than the coal-burning locomotive.

Figs. 13 and 14 show graphically the average composition of exhaust gas and the completeness of combustion percentage calculated from these analyses for cars and trucks under various operating conditions. Each result is an average of tests on from 12 to 22 cars. Fig. 13 shows a comparison of gas analyses of light and loaded trucks operating at a speed of 6 m.p.h. on various grades. The down-grade tests are characterized by large percentages of oxygen ranging from 4 to 8.5 per cent, and at the same time large proportions of unburned gases in the exhaust. Similar results were obtained on idling tests or whenever the cars were operating on a nearly closed throttle. The least oxygen and the most complete combustion was found on the up-grade tests when the cars were operating with a well-opened throttle. The level-grade tests gave results intermediate between up and down-grade tests. There is also shown a somewhat more complete combustion when the trucks are tested with a load equal to their full rated capacity.

Fig. 14 is a similar graph of average exhaust gas analyses for other operating conditions in which the light and heavy-load tests have been averaged. The greater efficiency with which a truck operates as the speed approaches the maximum for the truck is shown very clearly at the left; as for example in the 10 m.p.h. tests up a 3-per cent grade, the completeness of combustion consistently increases from 69 per cent for light trucks to 78 per cent for heavy 5-ton trucks. The same tendency is shown in the 15 m.p.h. tests. In general the average completeness of combustion ranges from 65 to 78 per cent on level and up-grade tests; the general aver-

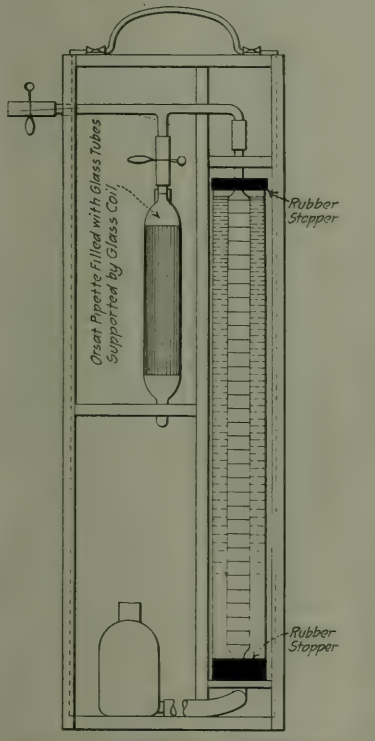


FIG. 15 — APPARATUS FOR DETERMINING CARBON DIOXIDE IN EXHAUST GASES

TABLE 6—COMPARISON OF EXHAUST GAS ANALYSES OF TESTS BY CHASE AND THE BUREAU OF MINES

	AVERAGE EXHAUST GAS ANALYSIS BY VOLUME, PER CENT					
	Carbon Monoxide			Carbon Dioxide		
	Chase	Bureau of Mines	Difference	Chase	Bureau of Mines	Difference
Car Standing—Engine Idling	2.6	7.1	4.5	8.4	7.9	0.5
Cars Accelerating from Rest to 10 m.p.h. on a level road[17]	1.9	5.5	3.6	10.1	9.5	0.6
Cars Running 10 m.p.h. on a Level Grade	2.3	7.3	5.0	9.7	8.6	1.1
Cars Running 15 m.p.h. on a Level Grade	2.5	6.8	4.3	9.5	9.0	0.5
Average	2.3	6.7	4.4	9.4	8.7	0.7

[17] In the Bureau of Mines tests the speed was 15 m.p.h.

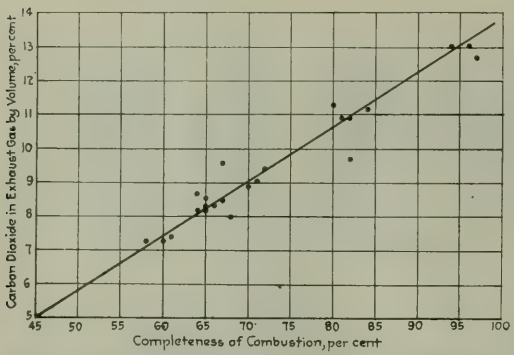


FIG. 16—RELATION BETWEEN THE PERCENTAGES OF CARBON DIOXIDE IN EXHAUST GAS AND THE COMPLETENESS OF COMBUSTION FOR PASSENGER CARS AND LIGHT TRUCKS OPERATING UNDER WINTER CONDITIONS

age for all cars and trucks being approximately 70 per cent.

PERCENTAGE OF CARBON DIOXIDE IN EXHAUST GAS AND COMPLETENESS OF COMBUSTION

The exhaust gas from the gasolines used in the tests should contain from 14 to 15 per cent of carbon dioxide on complete combustion of a theoretically correct mixture with air, without any excess of either gasoline or air. As the combustion becomes less complete the percentage of carbon dioxide decreases proportionally. It is therefore possible to construct curves showing the relation between the percentage of carbon dioxide and the completeness of combustion. These curves can then be used in estimating the completeness of combustion from a carbon dioxide determination with a simplified Orsat apparatus[18] as shown in Fig. 15 in the same manner as the powerplant engineer checks up the efficiency of combustion in a boiler furnace.

Figs. 16, 17 and 18 show such curves constructed from tests of passenger cars and trucks running at 10 and 15 m.p.h. up a 3-per cent grade. Up-grade tests are better for this purpose than level-grade or idling tests on account of the necessity of having a steady load on the engine to minimize fluctuations in the fuel mixture supplied. These curves also serve to show at a glance the wide range of combustion efficiency found in the 101 motor vehicles tested in this investigation. Fig. 18 which represents three classes of trucks from 1½ to 5 tons capacity shows completeness of combustion ranging from 55 to 95 per cent. A little intelligent attention to carbureter adjustment with the help of some carbon dioxide determinations should result in raising the carbon dioxide content to above 10 or 11 per cent, which would produce a saving of at least half of the 30 per cent of the heat in the gasoline now escaping in the exhaust gases as carbon monoxide, hydrogen and hydrocarbons. A change of carbureter adjustment to this extent would not impair the flexibility of operation. It is of course well known that theoretically perfect mixtures with absolutely no unburned gases in the exhaust do not give flexibility of operation on account of the lower velocity of flame propagation. However, good operating characteristics are readily obtained with 12 to 13 per cent of carbon dioxide in the exhaust gas which represents 85 to 90 per cent completeness of combustion.

[18] See Bureau of Mines Bulletin No. 74 entitled Methods of Analyzing Exhaust Gases by G. A. Burrell, p. 73.

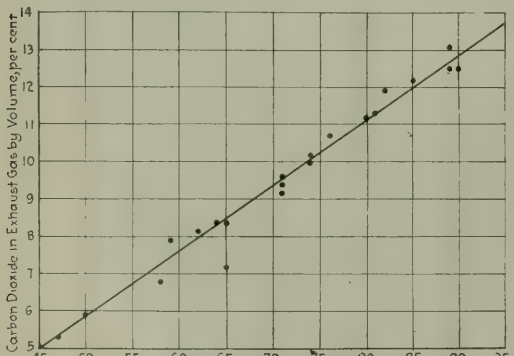


FIG. 17—RELATION BETWEEN THE PERCENTAGES OF CARBON DIOXIDE IN EXHAUST GAS AND THE COMPLETENESS OF COMBUSTION FOR PASSENGER CARS AND LIGHT TRUCKS OPERATING UNDER SUMMER CONDITIONS

SUMMARY

Road tests were conducted at Pittsburgh on 101 passenger cars and trucks of various capacities to determine the amount and composition of the exhaust gas discharged under the various conditions of speeds and grades that may prevail in vehicular tunnels, and especially the particular conditions of the Hudson River Vehicular Tunnel. The results of these tests have shown that

(1) Automobile exhaust gas consists of carbon dioxide, carbon monoxide, hydrogen, hydrocarbons, oxygen, nitrogen and water vapor, the relative proportion of these constituents varying greatly in the exhaust from different engines, depending on carbureter adjustment, degree of atomization, compression, etc.

(2) The important constituent of exhaust gas as regards tunnel ventilation is carbon monoxide. Physiological tests on exhaust gas reported by Dr. Yandell Henderson show that the maximum allowable concentration of carbon monoxide in air for 1-hr. exposure is four in 10,000

(3) The percentage of carbon monoxide for the various individual cars varied from 0.5 to 14.0 per cent.

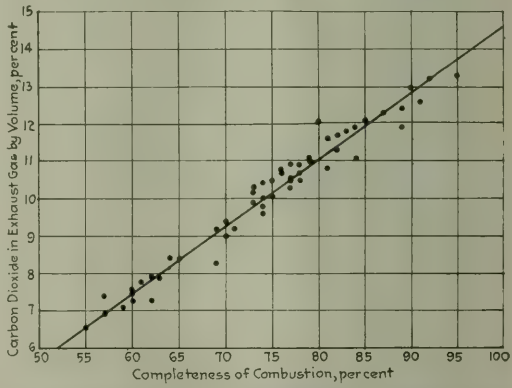


FIG. 18—RELATION BETWEEN THE PERCENTAGES OF CARBON DIOXIDE IN EXHAUST GAS AND THE COMPLETENESS OF COMBUSTION FOR TRUCKS OVER 1½-TONS CAPACITY OPERATING UNDER SUMMER CONDITIONS

Passenger cars and speed trucks on level grades at 15 and 20 m.p.h. averaging 7.0 per cent and 1½ to 5-ton trucks at 10 m.p.h. averaging 7.3 per cent. Seven to 7.3 per cent of carbon monoxide corresponds to an air-gasoline ratio of 11.8, a slightly richer mixture than is required for developing the maximum power. The maximum power mixture ratio is 12.5; the maximum thermal efficiency mixture ratio is 16.0 and the complete combustion mixture ratio is 15.0

(4) The larger percentages of carbon monoxide are produced when the throttle is nearly closed, as when running down grade or the car standing with the engine idling. The largest quantity of carbon monoxide is produced when the gasoline consumption is greatest, as with cars accelerating or running up grade at maximum speed

(5) Completeness of combustion varies directly as the percentage of carbon dioxide in the exhaust gas and inversely as the percentage of carbon monoxide. For the same carbureter adjustment in a given engine combustion is most complete with the engine operating under full load at its normal speed. However, the completeness of combustion of different cars varies greatly under the same condition of test. The primary factor in causing this difference appears to be the carbureter adjustment. The total range for different cars was 50 to 95 per cent. The average for all cars was about 70 per cent

(6) The combustible gas in the average automobile exhaust from 1 gal. of gasoline contains nearly 30 per cent of the total heat in the original gasoline. Thirty per cent of the 4,000,000,000 gal. of gasoline consumed in 1919 amounts to $400,000,000, with gasoline at 33 cents per gal. Careful carbureter adjustment should result in saving half of this amount

(7) The great majority of motor cars and trucks are operated on rich mixtures suitable for maximum power but very wasteful from the standpoint of gasoline economy

(8) The average motor-car carbureter is set for winter operation and is not changed in the summer, as shown by the higher percentages of carbon monoxide and the richer mixtures found in the summer tests

(9) The public should be impressed with the saving in gasoline resulting from the use of lean mixtures. If the builders of automotive engines would provide for the installation of a small gas sampling tube in the exhaust pipe of engines, especially on trucks, it would tend to introduce the use of carbon dioxide determinations for the control of carbureter and other adjustments. Taxicab and trucking companies could well afford to employ a chemist to make regular control tests. He could save his salary many times over, in cutting down the gasoline consumption

CONFERENCE ON TRAFFIC REGULATION

REPRESENTATIVES of 32 organizations interested in the enactment of a uniform motor vehicle law in the various States, attended the National Conference on Highway Traffic Regulation held in Washington in January. The Society of Automotive Engineers was represented by Major J. M. Ritchie of the Quartermaster Corps.

The Drafting Committee presented a report consisting of a proposed vehicle law based on recommendations sponsored by various organizations. This report was discussed at length. Parts of the proposed law were tentatively agreed upon and other sections referred back to the Drafting Committee.

As a result of the Conference, there was adopted a set of 'principles" on which the proposed uniform law could be based. It was understood that no final action of the Conference should be taken on the law itself but that the law as revised should be submitted to the various organizations interested, any organization being privileged to print such law over its own name if desired but without any mention of the other conferring bodies.

The Principles provide for the administration of the law preferably by a Vehicle Commissioner appointed by the Governor or if necessary by a distinct division of an existing State department. Full power, subject to review by the courts, should be given to refuse, suspend or revoke registrations and operators' licenses.

It is recommended that registration fees should be based on both horsepower and weight except in the case of agricultural vehicles and that operators' licenses should be granted only after the passing of a satisfactory examination. Maximum rates of speed should be fixed at not less than 30 m.p.h. in open country, 20 miles in residential districts and 15 miles in business portions; and a uniform method of hand signaling should be prescribed, denoting the operators' intention of turning, stopping or backing.

Obligatory equipment is described as consisting of the necessary sounding device, suitable brakes and adequate lighting equipment; the lighting specifications to be such as those of the Society of Illuminating Engineers under date of June, 1920, to which the S. A. E. Recommended Practice for Head-Lamp Illumination Operating Requirements as given on page B6, Vol. I, S. A. E. HANDBOOK conform. All trucks should plainly show the allowable gross weight of the vehicle and the load and the seating capacity in the case of those carrying passengers.

Definite wheel, axle and total loads should be established which should be varied according to the kind and width of tires. Rules of the road should be specifically stated, and municipalities given the authority to establish reasonable regulations not inconsistent with the State law.

Among other items covered is the requirement that the owner report to the Vehicle Department all cases of accident, court convictions as the result of accidents and cases of theft. Rules for pedestrians are also suggested.

The Conference expressed its approval of the present efforts to eliminate dangerous grade crossings and also recommended that red lights be used exclusively to denote extreme danger, except in the case of tail-lights; green lights to be used for all other traffic regulation.

The Bureau of Standards was asked to make a study of a uniform system of highway signs, including height, location, color, size and arrangement of letters.

Although no permanent organization was formed and no definite provision made for future meetings, S. J. Williams was elected Secretary of the 1921 National Conference on Highway Traffic Regulation for the purpose of acting as a clearing house for the various organizations represented and of communicating with them when desirable as to possible future conferences.

Passenger-Automobile Body-Designing Problems

By Andrew F. Johnson[1]

Annual Meeting Paper

THE designer must know first what purpose the body is to serve, and then decide upon its exterior appearance in connection with the car as a whole. The body is only a part of the car and cannot, in the general scheme, be considered separately. After the shape has been decided upon, the designing of bodies to carry passengers is included under three heads; safety, comfort and elegance.

To carry passengers *safely* is the first consideration of the designer and in this matter he meets his first problems. To be safe, the body must be strong in its wood and metal parts. These parts must be joined so that with ordinary usage they will hold together and maintain the shape and stability of the body as it was first constructed. But the body must be kept as light in weight as possible; so the first care of the designer is to produce something strong and at the same time not heavy. To do this he must exercise his best skill as a constructor. Protection from the weather is a necessary feature of the design and doorways of sufficient width to be safe for entering or leaving the car, having no sharp angles or other things to catch and tear clothing must be provided. Harmful drafts of air must be avoided, especially in closed cars, but there must be good ventilation.

After the matter of safety has been carefully attended to, the next consideration is that of comfort. Passengers naturally demand that they shall be able to ride all day in an automobile without being cramped or lamed any more than they would be in the best railroad cars. Comfort in a car depends principally upon the design of the seat. There must be a sufficient height from the floor that the passenger can at least get his heels back far enough so that his knees form a right angle. He cannot ride for long periods of time in comfort without being able to shift his position, and especially the position of his feet and legs. There must be plenty of room for extending the legs to their full length. The seat should not be so wide from front to back that the passenger cannot bend his knees to get his feet back without striking the calves of his legs against the front of the seat while his back is resting against the back of the seat. The seats must be wide enough from side to side to be comfortable for the number of passengers they are designed to carry. If the car is of the closed type, there must be headroom enough to prevent the hats of the passengers when seated from touching the inside of the roof. Nothing is more exasperating to a passenger than to have his hat rubbing the lining of the roof. It is essential that there be an absence of unnecessary noises, such as the rattling of doors, windows and the mechanism of folding seats.

The users of automobiles expect something more than safety and comfort in a car; they demand a certain degree of elegance. Exterior elegance includes correct proportions of the body in connection with the rest of the car, pleasing lines which do not conflict with each other, well fitting and properly hung doors and correct coloring in the painting. Interior elegance calls for pleasing upholstery, which should harmonize as to color with the painting of the car, carefully arranged lighting in closed cars and artistic appointments.

The foregoing are some of the problems met with in designing passenger bodies for automobiles. The designer of special bodies, for customers who furnish their own running-gear, meets problems not encounted by the designer for "production." The opposite of this statement also is true. Of the two, I think that the designer for production sometimes has the harder proposition. For instance, traveling men from different parts of the country bring their ideas in to the home office and many times the opinions expressed vary as to the same part of a car. All the suggestions must be considered, as well as the views of the heads of the firm. From them all, the designer must produce a car that will please the majority of the average buyers of the whole country, and perhaps of the whole world.

One other thing should be borne in mind, especially in designing high-class bodies; it is that after all has been said and done the car is only an adjunct. The car is made to carry people and the people are to be considered first. Therefore, the embellishment of the car, and especially of the upholstery, should be subdued as to color so that the dresses and wraps of the ladies will bring out the full beauty. The car should be a foil for the toilettes of the ladies who ride in it. This is especially true of town cars.

I believe that the "best" car has not been built. I hope to see the time when the mechanical and the body designing engineers in every automobile factory will get together when a new car is to be designed. They should remember that the car about to be built is for the express purpose of carrying passengers, and provide room enough between the dash and the rear so that the passengers can be accommodated. I am glad to be able to say that this is now being done in the best factories. The problems of the body designer are thereby reduced, and the worth of the car as a whole is vastly enhanced without extra expense.

We have become accustomed to look to Europe for the best examples of high-class passenger automobiles, but I believe that in the near future this will not be true. I trust we shall see the time when the European builder of fine cars will say to a prospective customer: "This car is as well built and as well finished as the best American car." With the consummate skill, untiring energy and splendid loyalty of the designers of cars in America, I see no reason why this desire shall not be realized.

[1] Principal, Correspondence School for Automobile Body Makers, Designers and Draftsmen, Gray, Me.

Ignition from the Engineman's Viewpoint

By Capt. George E. A. Hallett,[1] U. S. A.

Metropolitan Section Paper *Illustrated with* Diagrams and Charts

Abstract

Ignition is discussed in a broad and non-technical way. The definition of the word ignition should be broad enough to include the complete functioning of the ignition apparatus, beginning from the point where mechanical energy is absorbed to generate current and ending with the completion of the working stroke of the engine. The ignition system includes the mechanical drive to the magneto or generator and the task imposed on the system is by no means completed when a spark has passed over the gap of the spark-plug. Ignition means the complete burning of the charge of gas in the cylinder at top dead-center, at the time the working stroke of the piston commences. The means employed to accomplish this result is the ignition system. In the present-day type of gasoline engine a spark produced by high-voltage electricity is almost universally used for ignition. This high-voltage electricity is produced by a transformer. The transformer "steps up" the lower voltage produced from the source of current, which may be permanent magnets or a storage battery. Regardless of the source, the result must be efficient ignition if the maximum power output per gallon of fuel is to be obtained.

The whole program of events in an internal-combustion engine cylinder is then considered as having been slowed down, to assist in grasping the idea of what takes place, and three specific ways to make the charge burn faster are stated. Preignition and detonation are discussed, a statement of the advantages of using two spark-plugs per cylinder and a table showing power results with from one to four spark-plugs being given. Doped fuel is considered and the matter of certain and uncertain ignition is commented upon. Spark-plug tests at McCook Field are described and the mechanical defects in ignition systems enumerated [Printed in the November, 1920, issue of The Journal.]

THE DISCUSSION

A. L. Clayden.—Precisely what does the author mean by 118-lb. compression?

Capt. G. E. A. Hallett.—That is compression measured with an O Kill indicator, while the engine is running at 120 r.p.m. We generally speak of compression ratio, rather than of pressures.

Chairman A. M. Wolf.—We are fortunate in having with us Mr. Young, of the British Thomson-Houston Co. I believe many are acquainted with him or at least have read his book on magneto ignition.

Arthur P. Young.—Captain Hallett has referred several times to the necessity of having a "strong" spark. Exactly what does he mean by a "strong" spark? What is the particular characteristic that distinguishes what he calls a "strong" spark from one which he labels "weak"?

Captain Hallett.—I avoid that part of the discussion; I am extremely neutral and desire to keep the discussion away from battery versus magneto arguments.

Mr. Young.—I rather suspect that Captain Hallett has in mind the heat energy liberated in the discharge; that is, the joules per spark. If such be the case, it would seem that he has been advocating strongly a spark having those characteristics which are present in a magneto discharge, to meet the increasingly severe conditions that are likely to be imposed in the future by airplane engines designed for super-compressions and fed with fuel of low quality. The question of magneto versus battery ignition is a highly controversial one, and Captain Hallett wisely avoided all reference to it. I, therefore, could hardly have the temerity to raise this discussion, in the very home of battery ignition, but I cannot avoid making general observations on the results of Captain Hallett's experience and experiments with airplane-engine ignition.

In considering the process of ignition it is well to analyze exactly what happens when a high-tension spark is initiated. At the moment of separation of the contacts which control the primary circuit, and I am now dealing in a general way with either form of spark generator, the voltage induced in the secondary winding begins to rise from zero at a very rapid rate, in consequence of the sudden destruction, and reversal, with a magneto, of the magnetic field associated with the primary and linked with the secondary. We can look upon the complete high-tension circuit comprising secondary, high-tension lead and spark-plug, as possessing a certain amount of distributed capacity; so, in effect, we have linked across the spark-plug electrodes an imaginary condenser having a capacity equal to the distributed capacity in the high-tension circuit.

The secondary voltage grows at a phenomenally rapid rate, which is of the order of 300,000,000 volts per sec. at the moment of separation of the contacts in a high-tension magneto. As the secondary voltage increases in value, the imaginary condenser becomes charged and the voltage between its ends, and therefore between the spark-plug electrodes, rises with this extraordinary rapidity until it reaches the value E, which is the sparking voltage of the gap. At the moment this happens a spark occurs, and the imaginary condenser in question discharges itself across the gap with very great rapidity, giving in this first "bright-line" discharge an amount of energy equal to $\frac{1}{2}\ CE^2$, where C is the distributed capacity in secondary circuit in farads. After the first bright-line, or "condenser," discharge, comes a spark which persists for a relatively long period, this portion of the spark containing the electromagnetic energy that has been stored in the primary winding. It gives what is called the flamy part of the discharge, and it is this part which contains the greater portion of the heat energy liberated in the discharge. The two fundamental components of an ignition spark can be visibly observed on a rotary test-gap in which the discharge is spread over an arc of a circle by a rotating electrode. In this manner

[1] M. S. A. E.—Chief of powerplant section, engineering division, Air Service, Dayton, Ohio.

the first discharge can be observed as a single bright line, and the other portion of the spark is seen as a colored flame spread over a considerable angle. The duration of the first bright-line discharge is probably considerably less than 1/100,000 sec. Recent research has demonstrated that under ideal conditions this is the component of the spark which causes ignition. What follows is of little value from a purely ignition standpoint.

The fundamental distinction between a magneto spark and the spark generated by a battery-coil system is that, in the latter case, the flamy portion of the spark is not so highly developed. This means that at cranking speed and above, the heat energy in a magneto spark is considerably greater than that liberated by the spark generated by the other system. If, as I have already stated, the first portion of the spark is responsible for ignition, it might be assumed hastily that there is no advantage in having a flamy portion which persists for a considerable period of time. Viewing the problem from this angle, one could rightly conclude that it is desirable to make the first spark component as pronounced as possible; in other words, E must be as large as possible, the distributed capacity being controlled mainly by the characteristics of the high-tension circuit external to the spark generator. As a matter of fact, the view is now generally held in England that, in designing any form of spark generator, it is desirable to obtain a secondary-voltage wave-front which is as steep as possible. That is, the rate of voltage rise in the secondary at the "break" should be made exceedingly high and, other things being equal, this is a factor which determines the capabilities of a machine as a spark generator.

But we still have to consider the question of spark energy; that is, the efficacy, or otherwise, of the flamy portion of the spark. Although this may be of no value under ideal conditions, it does not follow that it is not desirable to generate a flamy component because, in practice, the conditions are frequently far from ideal and it is these adverse conditions which really determine what the characteristics of a spark should be. When everything is cold at starting, for example, the mixture enters the cylinder in the form of a mist, and it is easy to picture gasoline globules of considerable diameter floating about in the airstream that passes across the spark-plug electrodes. It is reasonable to suppose that under these conditions the heat energy liberated by the spark serves a useful purpose in vaporizing some of the globules and thus producing in the path of the spark a localized mixture of gas and air which approximates the ideal. A simple calculation shows that a spark containing only 0.03 joule of energy is capable of vaporizing 10 globules of gasoline each of which is 0.01 in. in diameter. Almost any magneto will generate a spark which does not contain less than this amount of heat energy at a cranking speed of about 100 r.p.m.

To obtain easy starting, therefore, one can safely assume, I think, that it is an advantage to generate a spark which contains a considerable amount of heat energy. This is becoming increasingly true now that the quality of the fuel available is degenerating rapidly. The view is frequently expressed that the magneto is obviously at a disadvantage as compared with the other ignition system, at starting, for the reason that in the latter case the best spark is produced at zero speed. While this latter statement is perfectly true, the argument is not quite sound because, in actual practice, we are concerned not with zero speed, but with the cranking speed of say 100 r.p.m. At this speed a well designed magneto gives a spark which contains certainly not less heat energy than that liberated by the spark of the other system. In the latter case the sudden drop in the battery voltage produces an enormous reduction in the heat energy of the spark which is approximately proportional to the *square* of this voltage. The spark-energy curves given in Fig. 1 are of interest in this connection.

Considering the normal running condition, it can be rightly conceded, I think, that with the engine thoroughly warm and the carbureter functioning in a suitable manner, satisfactory ignition will occur so long as there is a spark, and that the heat energy of the spark is not of paramount importance. We are faced here with a condition where the first component of the spark is the master of the situation. Admitting all this, however, what are the factors which determine whether or not a spark shall occur? Fundamentally, the answer is simple. A spark will result if the voltage rise across the spark-plug electrodes reaches the sparking voltage of the gap. But under working conditions there are two main factors operating which tend to retard the rate at which the secondary voltage rises, thereby tending to prevent the sparking voltage being reached and in consequence the occurrence of a spark. These factors are (*a*) excessive distributed capacity in the high-tension cables and (*b*) excessive leakage in the high-tension circuit, more particularly in the spark-plug itself.

To guard against undue slowing up of the rate of voltage rise, it is necessary to design the spark generator to liberate in the spark a considerable amount of heat energy and, apart from the question of ignition per se, the spark generator which gives the spark of greatest heat energy will, other things being equal, be best able to meet the adverse conditions that are imposed by the two factors (*a*) and (*b*). I have in mind the case of a certain airplane engine where it was necessary to use braided high-tension cables to eliminate wireless interference. The distributed capacity was thereby increased to such an extent that, at high speeds, missing occurred simply because the voltage induced in the secondary was so retarded in its growth that it did not reach the sparking voltage of the spark-plug gaps. This occurred with a magneto. With unbraided cables, giving a much lower distributed capacity, the ignition was perfect.

I was extremely interested in the supercharger designed by Dr. Moss of the General Electric Co., referred to by Captain Hallett, because it so happened that it was my privilege to be associated with Dr. Moss some 12 years ago in this country. The use of a supercharger raises an interesting point in connection with the design of spark generators; that is, the question of the safety spark-gap. In the ordinary way the sparking voltage of the safety-gap decreases with increase in altitude almost in proportion to the decrease in air density, but this is not detrimental because the sparking voltage of the spark-plug gaps falls off in much the same way, thus insuring that the sparking voltage of the spark-plug gap is always less than the sparking voltage of the safety-gap. If a supercharger is used, this relationship will no longer hold and, at a certain altitude, the plug voltage will become equal to the safety spark-gap voltage. Missing will then occur, and this will become progressively worse with any increase in altitude. The logical way of obviating this difficulty would seem to be to enclose the safety spark-gap in a small glass tube filled with some inert gas, so that its sparking voltage is unaffected by atmospheric conditions. This arrangement will give a constant sparking voltage at all altitudes.

DR. R. H. CUNNINGHAM:—Mr. Young has expressed my ideas in a general way in regard to the action of the magneto spark. Captain Hallett mentioned the increase in horsepower in connection with the use of two simultaneous sparks, running up even as far as four sparks. About 10 years ago, being connected with one of the largest American magneto companies, I brought out a two-spark system in which the energy of the spark-coil could be utilized on either the intake plugs or the exhaust plugs, or on both at once. In using these twin sparks, ordinarily we have to take certain electrical precautions. Generally, the frame of the automobile acts as a condenser of fair capacity and, unless certain precautions are taken in the setting of the spark-plug points, if one measures the time interval between the two sparks it will often be found that one spark occurs slightly later than the other. At that time I constructed an apparatus whereby we could measure the occurrence of the sparks within 1/100,000 sec., and it was very evident that under certain conditions these sparks could vary. Some very curious results occurred in certain kinds of engines with the gasoline that was then in common use. In some engines it was found that, instead of getting increased power with the two sparks, we got considerably less power. The two sparks apparently would cause an instantaneous or an almost instantaneous explosion of the charge, seemingly so quick that the piston would not respond properly to this sudden explosion, the gas being too suddenly and entirely consumed and not burned as under ordinary conditions.

Then I built a four-spark apparatus in which two magnetos were synchronized, but they were actuated by one circuit breaker. In the particular engine to which this was applied there was no increase in the power because of using four spark-plugs instead of two. In fact, in that engine, a single-spark magneto that had about 10 deg. advance greater than the ordinary single-spark magneto was capable of giving the same amount of power as with two sparks. So, when these double-spark magnetos were applied to various motor boats, having engines of moderate speed or, comparatively speaking, slow-speed engines, the two sparks were extremely detrimental. On high-speed racing cars, however, having very high piston speeds, the two sparks were advantageous. Some years later, when using a magneto which would allow an 80-deg. advance, this magneto giving an extremely hot-arc spark on a very long-stroke engine, it would do about what the two-spark ignition would do. The point is that if we increase the number of sparks, we are very liable at the low speeds to get too rapid firing of the gas. In that way we get a variety of "knock" and the piston speed falls off. To avoid this we had to increase the gasoline consumption by making the mixture richer so as to burn somewhat more slowly, thus compensating for the sudden detonating type of firing. If carbureters can be arranged so that we can adjust for these difficulties, the use of ignition apparatus with the ordinary degrees of advance will probably result in an increase in power if two sparks are used.

In reference to spark strength, hot sparks and the like, one great difficulty is to find a method of measuring exactly the maximum strength of the current in a spark. The heat depends upon the current strength and it is really a very difficult thing to say exactly how many milliamperes exist in a spark from an induction coil or from a magneto. Such currents are very rapid and usually are beyond the capacity of most registration apparatus. Merely because there is a spark across the spark-plug, it does not necessarily follow that with each different variety of ignition apparatus the character of that spark will be the same. There may be a single spark or intermittent sparks. As mentioned by Mr. Young the rise in voltage by which the capacity of the circuit, secondary winding, the spark-plugs and the cables, is charged, may be enough to jump the gap, forming just one spark, or a few uni-directional intermittent sparks, or even several damped oscillatory sparks. The charge may jump the gap and, after the occurrence of one or more oscillations, a small arc form which may or may not imitate a large or a small explosion accompanied or not accompanied by a knock. My experience with various ignition systems has been that when the voltage is sufficient to produce an arc concomitant with the first spark,

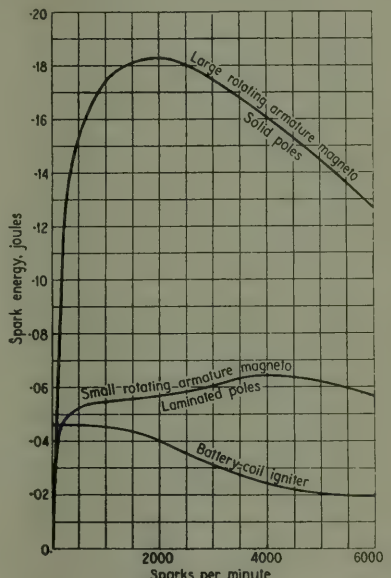


FIG. 1—SPARK-ENERGY CURVES OF DIFFERENT IGNITION SYSTEMS

we get the best results. The weakest mixtures can be used then, and the gasoline consumption is thus diminished considerably. As already stated, there are varieties of apparatus in which the rises of voltage occur as follows: The electrostatic charge jumps the gap, the voltage drops almost instantly and that spark ceases. The voltage again rises and the first spark is followed by one or two feebler sparks. With this type of "spark," knock will often be established. It is difficult to say to just what the effect is attributable.

I think it was Dr. Watson who found out that, after an engine heated up and got running, the intensity of the spark could be reduced very greatly. My own experience agrees with his. I pointed that out, about 1915, at the Indianapolis meeting. But it is at the beginning, when the engine is cold, when poor gasoline and low temperatures prevent the vaporization of the gasoline, that the arc spark is desirable. When there is only a kind of a fog or mist in the cylinders, heat must be generated at the spark-plug so as to produce real gas; this makes the heat valuable. For some time past I have

been experimenting with a magneto in which the energy is concentrated so as to produce a maximum primary voltage and a secondary current which lasts a very small proportion of the time of the half cycle but which is intense enough and lasts sufficiently long to ignite almost any fuel, even raw kerosene. So, I think the hotter the spark is, particularly when in the form of an arc, the better able we are to fire and utilize present-day fuels.

A MEMBER:—I think the previous discussion has shown the state of science at present in the ignition field. It is that we really do not know very much as yet. I will relate some experiences I had some time ago in connection with experiments with a small stationary engine. The problem was just what ignition system could be adopted for the then state of the art. I had a small stationary one-cylinder engine the cylinders of which were some 4 or 5 in. in diameter. I first used four dry-cells and the coil and took a diagram with a regular steam indicator of English make. After that I ignited the same engine with the hot tube and took the same diagram. Then I took a diagram using the make-and-break system, which gives a low, emphatic, long spark. Bosch brought out one of his magnetos just at that time. I rigged one up, ignited the engine with this magneto, and took a diagram. When these diagrams were compared, we saw that if there was an increase in power, it would be in favor of the hot-tube method. But, with good carburetion, the diagram was almost absolutely the same with the four-cell dry-battery spark with the small coil, as with the big make-and-break emphatic spark. It seems to me that, with conditions of carburetion, it is almost immaterial what kind of spark is used to ignite the mixture. With a cold engine or imperfect carburetion conditions, the diagram might be slightly larger, if four, five, or six spark-plugs were used. This is a much more intricate problem than it appears to be. Experimentation is rather difficult. It is very hard to get an exact indicator. The same engine must be operated with different systems of ignition and with different locations of spark-plug to obtain comparative results. The location of the spark-plug in the cylinder seems to have a considerable effect on the output of engines of the same dimensions. It seems to me that neither on top of the inlet nor near the exhaust valve is the right location. This problem has not been solved so far as my experience goes.

Regarding the unexplained phenomenon of the auxiliary gap, I am experimenting with a Ford engine on which I have been able to measure the output. It seems that the auxiliary spark-gap gives a considerably greater economy. I have not been able to determine what the reason is, but the fact remains that if the same spark-plugs and the same ignition system are installed on the same engine, the carburetion can be cut down and a leaner mixture can be ignited with an auxiliary spark-gap than without one. The size of the spark-gap itself seems to be related in some degree to the engine compression. Just what the relation is I have not been able to determine.

M. E. TOEPEL:—I experiment with engines that are used in every-day practice, and we encounter some very knotty ignition problems. I think that the composition of the spark-plug electrode is one of the things that needs the greatest revision at present. The ordinary 98 per cent nickel electrode used today is not sufficient; a metal is required that can withstand more heat than that can. I read recently that in England they are coming to tungsten. I agree with what Captain Hallett said in regard to cavity; in other words, we should avoid any more cavity in a spark-plug than is actually necessary.

Captain Hallett said that in setting fire to a brush pile it is better to ignite it completely around the circle. If the wind is blowing in a certain direction, that is not necessary; it can be set on fire on three sides and the natural draft will take care of the rest of it. The statement that the propagation of flame is like the effect of throwing a stone into water, is incorrect. That applies to the early and better type of fuel. Turbulence is required for the present type of fuel. It has been said that we need more spark heat. Whenever we have applied more spark heat, we have found that the electrodes of spark-plugs would not last very long. Consequently, if the manufacturers give us ignition having very high spark heat, the present spark-plugs will need to be readjusted almost every day.

Concerning the mixture itself and the location of the spark-plug, I think we have not determined the correct location. This has a bearing on the heating of the valves. Under ordinary conditions we cannot change the spark-plug location easily on an engine.

In practical every-day engines, not including high-powered airplane engines, we find that ordinary two-spark ignition does not increase the power; but it gives smoother running and a great saving in gasoline, irrespective of where the spark-plugs are placed. Even if we place the spark-plug directly over the exhaust valve, we find it runs much cooler when idling and lowers the gasoline consumption, but it develops lower power.

How far has doped fuel progressed? Will it be made in commercial quantities? Can we experimenters obtain it? Mr. Kettering mentioned anilin and other chemicals of similar nature. Are they procurable at present?

CAPTAIN HALLETT:—At present the General Motors Research Corporation is working on many different compounds. They have used one called anilin oil and another called xylidin. I think neither is obtainable in the ordinary sense, but I believe the organization named would provide some for experimental purposes. I know they are planning to use cheaper compounds and are finding ways to make these in much larger quantities. They are arranging also for very complete distribution and those compounds will be available eventually. One way to start such work is to use benzol in the fuel; 20 per cent of benzol will take the knock out of an ordinary engine.

MR. TOEPEL:—I do not know whether every engine will rise to 160 lb. per sq. in. compression pressure, but I think some of them can make use of higher compression.

A. R. MOSLER:—How are self-ignition and preignition defined?

CAPTAIN HALLETT:—I know of no difference between premature ignition and self-ignition. I call them both preignition. I only tried to differentiate between that phenomenon and the phenomenon we call knocking, in which case merely detonation of the remaining portion of the charge exists. I feel that "pre" or early ignition and self-ignition are the same.

MR. MOSLER:—About 20 years ago, when making experiments with carbureters, we used a very lean mixture and obtained extremely high speeds with no power at all. We noticed also at that time what we did not recognize was detonation of the gases. The most essential feature in spark-plug construction to prevent preignition is that the plug shall be absolutely gas-tight.

WILLIAM HASSELKUS:—Has any particular difference been found in testing engines between wiring one mag-

neto entirely to the exhaust side and one to the inlet side, rather than wiring to each cylinder bank? If wired to the exhaust sides and inlet sides through each magneto, has any particular difference been found in setting the exhaust side, say about 3 deg. ahead?

GEORGE J. MEAD:—There was a difference, but it was very slight. As I remember it, the magnetos attached to the exhaust plugs were the ones having a slight advance over those on the intake side, to get the best power.

CAPTAIN HALLETT:—It is not the present brake mean effective pressures resulting from present-day compressions that force us to design engines as strongly as we do, but rather the uncalculated strains imposed by occasional preignitions. The use of 160 lb. per sq. in. compression pressure, together with fuel which will not preignite would, in my opinion, cause no distress in present engines.

CHAIRMAN WOLF:—In covering the subject of ignition in its broad sense, this session would not be complete without discussing it insofar as it applies to Diesel engines. Therefore, I ask that someone tell us about "ignition" as applied to these engines.

Perhaps there is no difference in spark strength with magneto and with battery ignition, but I am inclined to believe there is. Captain Hallett and I ran some tests at McCook Field with a Liberty engine equipped with both ignitions. One part of these tests was an idling run of 1 hr., during which we used large amounts of oil which the engine utilized at full throttle, the additional oil being supplied through the air intake to the carbureters. The spark-plugs looked cleaner after they had been run with the battery system than when run with the magnetos. The reason for this we could not explain. I have since wondered if this condition had some relation to the strength of the spark. For example, if we contend that the battery-ignition spark is not so hot as the spark from the magneto, perhaps the plugs would be cooler and the oil would not carbonize on them; whereas, the arcing spark of the magneto possibly carbonized the points.

V. W. PAGÉ:—What of the automobile engine designer who must design parts that will withstand the brake mean effective pressure resulting from 160 lb. per sq. in. compression pressure, and keep the weight and the cost down?

ELMER A. SPERRY:—Diesel engines do not use spark-plugs. They get ignition by high temperatures and then injecting the fuel. We have an idea that this is the coming way to obtain ignition. Diesel engines run under a tremendous handicap as regards compression space; they have chilled walls and very low fuel content, but they show excellent economy owing to the high compression and high temperatures. We believe that, although those engines are handicapped by the extra super-compressed air necessary to energize the oil as it comes in, when we eliminate this as it seems we can and have a large-sized clearance space on top of the piston, possibly those two things together would develop the Diesel cycle and make it light enough so that we can employ it in regular automotive work. We are making steady progress toward this end. With the Diesel cycle available, we would not be tied down to gasoline and would be relieved at once from many difficulties, especially those causing the negative loop on the indicator card. All explosion engines are handicapped in the matter of very close adjustment of mixture. When the mixture is right, we must do all further manipulating entirely with the throttle. Engines in actual service conditions are gasping for breath probably 95 per cent of the time; Nixon says 99 per cent. Of the small power that we then get, when the compression curve starts at sub-atmospheric pressure, a large part of that power has to be applied immediately to supply power to the negative side of the card and that power never becomes positive. Some of those things should be avoided.

The sum total of following the Otto-cycle explosive-mixture engine is that we are handling about 5 per cent thermal efficiency to the rear axle. I am a most thorough believer in the statements of Mr. Kettering that it will be common practice presently to deliver between 25 and 40 per cent thermal efficiency to the rear axle. We must save fuel; if, in saving quantity, we can do away also with the limitations in quality, those two things will be beneficial to automotive engineering.

WILLIAM C. BRINTON, JR.:—The need of a stronger spark to start the engine with has been mentioned. That is a very good argument for battery ignition because, if there is any class of ignition with which an excessively strong spark is produced at starting it is the battery ignition. We have been told that the great advantage of the magneto is that at high speed it has a very hot spark. I would like to have it proved that the heat of the spark of a magneto or one from a battery system is what accomplishes the desired result. With the make-and-break system, we have the temperature of the electric arc. With the jump-spark system of today it is practically impossible to prove that it is heat that accomplishes the result.

The Bureau of Steam Engineering received a report from the British Admiralty in January, 1918. They have conducted a test over a period of two years to determine what properties of the spark produced satisfactory ignition and in their conclusion they stated that they had not been able to find what produced satisfactory ignition but that they had proved that it was not heat.

The Seeley high-frequency system worked out rather disastrously on several passenger cars but under good conditions the system did work well. The high-frequency current objects to turning corners on such a system and under certain conditions nothing is obtained at the plug. In this system the current was purely a condenser discharge which is known as an ampereless discharge.

In regard to firing one or more plugs per cylinder, the advantage depends largely upon the shape of the cylinders. In a T-head engine, firing one plug over the intake, the magneto develops a given brake-horsepower. Firing two plugs simultaneously, one over the intake and one over the exhaust, an increase of 35 per cent in horsepower was shown. With L-head engines at low speeds we find very little difference. An engine on which we tested a plug over the exhaust was timed 3 deg. earlier than that over the intake and there was an increase of about 5 per cent in horsepower. This, however, is not always the case.

A. F. WAGNER:—Increased horsepower has been discussed, but I believe we are trying to get economy. With that increased horsepower, was the quantity of gas decreased? I have heard nothing about economy with increased horsepower.

CAPTAIN HALLETT:—In aviation engines we have always had better economy with the use of more spark-plugs. It has, however, been necessary to adjust the spark-advance differently with each number of spark-plugs. Did Doctor Cunningham adjust the spark-advance differently and in such positions as to get the best results with each different number of spark-plugs used?

DR. CUNNINGHAM:—The adjustments were made to get the best results out of the engines. We also could run the magneto very much further advanced than is ordinarily the case.

F. W. ANDREW:—Perhaps the effect of two spark-plugs at different speeds is not quite clear. I think the effect in relation to the shape of the cylinder has not been brought out. I think that nobody has made experiments to find out why the spark-plugs will give more power with the T-head engine at certain speeds. When we reach racing speeds, I do not doubt that the two spark-plugs will give better efficiency and economy also; but with truck engines, that do not ordinarily run more than 1000 r.p.m. and carry their heaviest loads at 500 r.p.m., we have a different problem. Rapid flame spread at this speed is not desirable.

Mr. Young spoke about what happens to the safety-gap when the Moss supercharger is used at great altitudes. I think there is no safety-gap in the ignition system that was used with that supercharger; that is cared for in another manner.

Regarding the doping of fuel, will this be done with present-day gasoline, thereby failing to increase our supply of gasoline, or with some such oil as fuel oil? What we are all interested in today is to increase the amount of gasoline available. I think we will not accomplish that by "doping." I think that is working along the wrong track. If we can dope a lower grade of fuel than gasoline, we will arrive somewhere. Is a lower grade of oil than the present grade of gasoline being doped experimentally now?

CAPTAIN HALLETT:—It is my understanding that Mr. Kettering hopes to dope fuel oil, as you suggest, and in that way make it possible to use fuel oil with compressions higher than those now used with gasoline; in that case we would have fairly clean burning in the cylinders due to the higher compression. I believe Mr. Kettering feels that when the distribution of "dope" is an accomplished fact and it is really available all over the country, new automotive engines and old ones already in service can be equipped gradually with much higher-compression pistons, in that way greatly improving the economy and, by allowing us to use lower grade fuel, greatly stretching the fuel supply.

As regards the supply of fuel, it seems that not enough benzol is available so that a mixture of 20 per cent benzol and 80 per cent gasoline can be used, thus eliminating knocking, or a 50 per cent benzol mixture, thus permitting higher compressions. Alcohol, I believe, would be a good anti-knock compound; but it will not mix with gasoline unless benzol also is present. It seems that while we shall be able to spread the supply of gasoline by doping it with alcohol and benzol, we also must stretch it by doping it with anilin oils and the other compounds that Mr. Kettering is developing.

FIG. 2—THE SPARK-PLUG IN THE SPARK-GAP

I hardly meant to recommend the use of compressions as high as 160 lb. per sq. in. in truck engines, but was trying more to point out to the ignition manufacturers that very high compressions and severe conditions are coming.

MR. BRINTON:—Do your experiments show whether it is better to have the spark at the top of the combustion-chamber or further down?

CAPTAIN HALLETT:—Dr. Dickinson has done work along that line. It is my understanding that he attained very favorable results by extending the spark-plug electrodes down into the center of the combustion-chamber. I believe he did this by using an ordinary spark-plug and making very long and very slender electrodes which would be chilled during the intake stroke so that they would not cause preignition.

MR. BRINTON:—We had trouble in doing that because by using a long plug with high compression preignition is bound to occur in practice.

CAPTAIN HALLETT:—I believe you are right. I think it would be very difficult to cool electrodes there, but I was assured that in this experiment of the Bureau of Standards they succeeded in keeping the electrodes cooled.

A. D. T. LIBBY:—I find myself heartily in accord with many things that Captain Hallett has said. I think he hit the keynote, so far as ignition is concerned, when he said that the ignition should be capable of burning the gas very rapidly. Whether ignition effect is like that of a stone thrown into a pond, or like a torch applied around

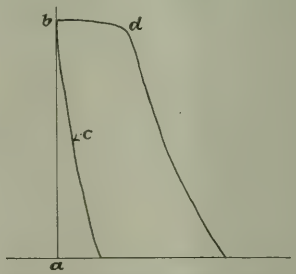


FIG. 3—DIAGRAM OF THE VOLTAGE WAVE FORM IN AN IGNITION SYSTEM

a brush pile, makes little difference; the point is that it must burn the gas very rapidly. Captain Hallett's idea of having a superfluous amount of heat in the spark appears to me to be the logical thing.

We have many things to contend with in an ignition system. The problem is not entirely that of the breaking down or jumping of the spark-plug gap. We must take care of the leakage in the various parts of the ignition system, such as the cables and the distributor, and of surface leakage in the spark-plugs themselves. The plugs become fouled with oil or moisture and the ignition system must have capacity enough to produce real ignition under such conditions.

Fig. 2 represents the spark-gap in the spark-plug. The system, running back to the distributor, must supply energy enough to charge the cable, take care of the leakage losses in the spark-plug, and finally get across the gap with sufficient energy to ignite the charge. When the charge is just right for rapid combustion, that is when the carbureter is working just right and there is a good resultant mixture, not much energy is required to fire the charge. But there are many times

when those conditions do not prevail; therefore we must have an ignition system that is capable of meeting all these circumstances in all kinds of weather.

Suppose we have an ignition system in which the initial wave-form has substantially a vertical rise, as shown in Fig. 3. The instant the spark-plugs become charged to the potential illustrated by the line *ab*, that is, the charging up of the cables to the point where the current is ready to jump the spark-plug gap shown in Fig. 2, if the spark immediately drops off in the manner shown at *c*, we have nothing to heat the gas around the vicinity of the plug at the instant of discharge, provided the curve of the ignition is of the form shown at *c*. It is my contention, therefore, and I have gathered from Captain Hallett's paper that it is his viewpoint, that the spark, instead of dropping off and back to the zero line at once, should remain at or near its maximum for a certain length of time, as indicated at *d* in Fig. 3, and then drop off. With a spark of the character indicated at *d* in Fig. 3, we stand more chance of burning all the poor mixtures. With a mixture that is extremely rich, particularly in cold weather, we encounter globules that have not really been vaporized.. If globules of fuel are in the vicinity of the spark-plug gap and we have a spark carrying a reserve value of heat, the heat spreads in the manner shown in Fig. 2, the spark shooting across the gap, instantly followed by what we term "whiskers," indicated by the shaded portions. which reach out to engage the mixture that is in close proximity to the spark-plug gap.

With such a spreading of the spark, we have much more chance of firing the mixture, because of the excess of heat at the instant of jumping. My view is that while this initial rise *ab*, in Fig. 3, must be very rapid, it should be followed by a definite amount of heat, indicated by *d*, to get the most rapid flame propagation.

A question was asked as to what is being done in the way of investigating the heat of sparks. The two upper curves of Fig. 4 illustrate a magneto on which I recently measured the heat value of the sparks; it is our regular everyday product and we consider it an excellent machine, but the magneto which gave the bottom curve has three times as much heat in the spark.

VICTOR GREIFF:—About the best that we can boast of at present is a spirit of earnest inquiry. We are doing all we can to cooperate with engine designers, engine builders, engine testers and spark-plug locaters, in this matter. In the meantime, if we have a spark which has that initial static discharge referred to by Mr. Young; that has, after that, a discharge of inductive energy, i.e. electro-kinetic energy; and that then has an electro-dynamic generated arc, which is the nature of the spark given by the old-fashioned magneto, we certainly have all the elements that can possibly be provided to do everything that can be expected of the spark. We have followed the work of Mr. Young with great interest, that of Mr. Morgan, who has, I believe, worked along similar lines, and also of a number of British investigators of great skill and insight who are the leaders in ignition research today.

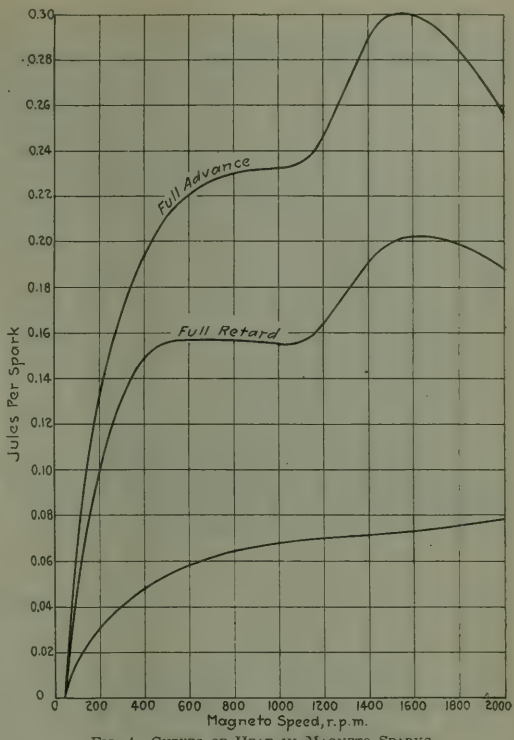


FIG. 4—CURVES OF HEAT IN MAGNETO SPARKS

A MEMBER:—We must break down the tendency for the spark not to jump through the compression. Captain Hallett says that if we raise the compression we must raise the voltage to penetrate it. Next, we must put the heat in after we have broken down that compression. So far as the spark-plug is concerned, when spark-plugs can withstand extreme heat, we will provide whatever heat is wanted.

MR. PAGÉ:—A company that makes both magnetos and spark-plugs has representatives present. What steps are they taking to keep their spark-plug construction up to the heat of their magneto spark?

E. A. ROBERTSON:—We think that the spark-plug we make will hold down any ignition system there is at present. Spark-plug engineers have been experimenting for years with high-compression engines but, so far as I know, there is no spark-plug yet that is satisfactory for use in engines with the high compressions Captain Hallett speaks of.

Looping the North Atlantic in the Typhoon

By William Washburn Nutting[1]

Motorboat Meeting Address — Illustrated With Photographs

IT is gratifying to feel that I am still eligible in such a gathering as this. After the harrowing press accounts of Typhoon's cruise, I felt that I might have lost my standing as an amateur sailor and skidded into a class with Steve Brodie and the chap who went over Niagara Falls in a barrel. Not that there was any particular purpose in the cruise. William Atkin and I designed the little ship and I had her built at Dr. Graham Bell's laboratory in Nova Scotia, and sailed her across the Atlantic and back again for the fun of the thing and incidentally to cover the International Motorboat Races for *Motor Boat*. Picking one's way across big stretches of water by newly acquired skill with the sextant, pitting one's wits against the big honest forces of nature, feeling the way with lead line through fog and darkness into strange places that the travelers of trodden paths never find at all, are worth the considerable cost, the time and even the risk that are involved in such an undertaking.

Sometimes I have difficulty in explaining this sort of thing as a "pleasure cruise," but I venture to say that if the truth were known we would find that a great many of the big expeditions, things that would make the cruise of the Typhoon sink into insignificance, were undertaken more from a love of adventure than from any profound scientific conviction. I met Bob Bartlett the other night, and you cannot tell me that Captain Bob was inspired by any scientific motive when he went to the Arctic. You cannot tell me that Theodore Roosevelt was driven through Africa and South America by a scientific itch. Of course, these people had a scientific excuse on which to hitch their undertakings, while we had not even a scientific shoestring to cling to. But why have any excuse?

One newspaper came out with a sort of double-barreled editorial in which it praised the cruise of the Typhoon as a "remarkable feat of yachting," but said that it was not sensible yachting nor hardly the thing for American yachtsmen to emulate because of the danger involved. Now we do not advise people to go puttering about the Gulf Stream in small boats in the middle of November, or to cross the Atlantic on the fiftieth parallel at any time of the year, but we hope that if anything comes of all this publicity, it will be to inspire, at least in the youngsters of the country, a desire to get back to the sea. Potentially, we are a seafaring nation. We have the finest coastline in the world and we have a heritage from the clipper ships that made the American ensign known and respected on all the Seven Seas. What we are suffering from in this country is too much common-sense. If you apply a common-sense or a "safety-first" limitation to any sporting venture, you emasculate it into a poor, weak, pale thing, unworthy of the name of "sport." There is no fun in such an undertaking unless it involves an element of danger and hardship.

The Outbound Voyage

The Typhoon is a 45-ft. auxiliary ketch-rigged yacht, 36 ft. on the waterline by 12-ft. beam and 6½-ft. draft. Her lines were drawn by William Atkin and she was built under the supervision of F. W. Baldwin at the laboratory of Dr. Alexander Graham Bell at Baddeck, Cape Breton Island, Nova Scotia. She was powered with a 7½-hp. engine of the high-compression, oil-burning type. Her performance has proved what has been proved time and again by such men as Day and Slocum and Blackburn, that a small boat properly designed and built is as seaworthy as a large one. Structurally, a small boat is stronger than a big one. There are dangers and hardships, of course, in such a cruise, but so far as the boat itself is concerned there need be no question of its seaworthiness.

We had planned to sail on July 1 to reach England by Aug. 10, the day set for the first of the International Motorboat Races, but I found when I reached Baddeck about the middle of June that the boat was nowhere near finished. We launched her finally on July 3, and by eliminating such things as trial trips, compass adjustments and the like, we were ready to hop off by the 18th. Our endless equipment and provisions were thrown aboard.

Then there was the matter of the crew. Baldwin was certain, but we needed two or at least one more man, and at the last minute we picked up James Dorsett, a youngster, who had been working on the Liberty engines of the HD-4; he had never been to sea but was willing to take a chance. We got under way at midnight and chugged out the Bras d'Or Passage under power. Then something went wrong with the engine. In the rush of leaving the city I had failed to visit the factory to learn certain things about the engine and the factory through some oversight had failed to send us sufficient information about various adjustments; in consequence the engine was not used again until we reached England. To make matters worse, we encountered a calm off the Cape Breton coast and our chances of reaching Cowes seemed practically nil. The logical thing would have been to put in to St. Pierre, Miquelon, or some other port and get the engine going, but I was afraid that once in the logical thing would be to stay, for our chances seemed to be about 1 in 100. There was no particular point in crossing if we could not make Cowes in time for the races. Then we encountered a gale and tacitly agreed to keep on for England. Providence favored us with hard southwest winds over the quarter, and under sail alone, and mighty little of that at times, we made the run from Cape Race, Newfoundland, to the Scilly Islands, in 15 days 9 hr., driving the craft every minute of the time. Although we got so tired that we could stand but

[1] Managing editor, *Motor Boat*, New York City.

an hour's watch at the wheel without falling asleep, and in spite of the fact that Dorsett was sick most of the way over, although able to take his regular trick, we soon became adjusted to the motion and were able to prepare regular meals and to sleep under any conditions.

Sailing up the English Channel with spinnaker set, we passed through the Needles into the Solent and dropped the hook off the Royal Yacht Squadron at Cowes at three o'clock in the morning the day before the first of the races. We were in time with 36 hr. to spare.

After a week in England Baldwin left us to confer with the Admiralty in regard to his glider, the HD-4, and it was necessary for us to look about for someone to fill his place. Finally a young chap named Fox, who is the master of the Sea Scouts of Cowes, and Hookey, one of his youngsters, signed for the return cruise. Fox had had a bit of cruising experience and Hookey knew enough of open-boat handling to pick up the work readily, and with a full crew of three, we left Cowes for the French coast.

Landfalls on the French and Spanish Coasts

As it was then the last of September there was little time for sight-seeing, and we decided to hit only the high spots and make New York before the winter weather. Crossing the Channel, we put in at a quaint little town called Roscoff on the Brittany coast. Having nothing but small-scale charts of the section, we cannot claim any particular credit for discovering one

The Author at the Wheel of the Typhoon

of the most picturesque places on the northern coast of France. We blundered in over what looked at low tide to be a range of mountains and spent a most delightful three days. It was our only stop in France. Rounding Ushant, we headed directly across the Bay of Biscay for the point of the Spanish peninsula and in due time picked up the coast in a fog. Appearing first as rocky islands in the sky, the land gradually took form as we approached, great rocky promontories with picturesque beaches between and mountains in the background that were as typically Spanish as if painted by Sorolla. It proved later that we had made the coast within a few miles of Cape Ortegal, our objective, proving that our navigation had been practically perfect, a thing that never failed to surprise me.

The town of Ferrol, indicated on our sailing chart, lay on a sort of indentation between Cape Ortegal and Cape Finisterre, and as this seemed to be a logical place to take on provisions for the hop to the Azores, we con-

The Typhoon Anchored at Cowes, England

tinued down the coast and finally reached a remarkable fiord at the head of which the town is situated. Ferrol proved to be the Portsmouth of Spain. Here Vickers of London builds His Majesty's battleships in the same dockyard in which Philip II built the ill-fated Spanish Armada in the sixteenth century. We were not particularly impressed with the place, which like many another military post is provincial and complacently benighted. Except for its harbor, which ranks among the finest of all Europe, and its picturesque qualities which are well up to the backdrops of the Metropolitan Opera, Ferrol left much to be desired. But not so Coruña, which was our next port of call. Coruña is a progressive town, much more typical of Spain, and it successfully counteracted the bad impression left by Ferrol.

From Coruña we took our departure for the Azores which we would have reached in eight days had it not been for a spell of calm weather. After 13 days we

Cleaning the Bottom in an Improvised Drydock at Roscoff, France

sighted the island of San Miguel and got in so close that we could count the toy houses on the cliffs, when a northwest gale struck us, snapping our mizen at the deck and forcing us to lie to under the trisail. For two days we rode it out on the port tack and then came about and rode for another day on the starboard tack, when the wind abated and we were able to hoist sail again and finally made the little island of Santa Maria, 54 miles south of San Miguel. As darkness came on, we made for what appeared to be a deserted little town, as there was not a light to be seen, due to the fact, we learned later, that the windows were all closed up with heavy wooden shutters. Feeling our way carefully with the lead we reached what seemed to be the center of a cove in the cliffs, the tops of which were silhouetted against the sky, and dropped the anchor and turned in. In the morning we found ourselves in the middle of a wonderful amphitheater with tiny pink and blue and buff houses along the shore, back of which miniature rockbound fields extended ladder-like, to the very sky. These fields were filled with grape-vines, each little house had its own wine press and one progressive native owned a still. We were practically out of food, and as we stepped ashore, a bit groggy from hunger, we were welcomed in English, for it proved that most of the natives had served their time in the shoe factories of Massachusetts. They passed us from house to house, wining and dining us, and we found it literally very hard to leave the place that afternoon.

Sailing all night, we made Ponta Delgada the next night and felt our way into the inner harbor with the lead. We found that eight American Shipping Board vessels had been driven into this port for repairs by the gale that had broken our mizzen. Going alongside one of them, the Independent Bridge, whose officers were most hospitable to us, we jerked out our mizzen and made the necessary repairs. The problem of food was a difficult one to solve as there was an embargo on many items, on account of the food shortage in the islands. If you have ever smuggled a dozen eggs in an ordinary business suit, you will appreciate the situation; the percentage of breakage may be small, but the damage is terrific. Even the salt beef and flour that we finally obtained from one of the American vessels had to be smuggled at night, for the little toy soldiers were always on the watch.

After a week at Ponta Delgada, we hopped off for New York. Our leaving was a most inspiring one. Each of the dozen ships then in the harbor broke out its siren and searchlight as we left the inner basin at nightfall; I imagine that the town had not heard such a racket since the American collier Orion beat off the German submarine. Since we were going against the drift of the weather, it was necessary to bend down south for favorable winds, and we headed about southwest until we reached the thirtieth parallel where we encountered a northeaster that lasted for a week during which we logged off 1031 nautical miles. It must have been the tip of the Northeast Trades. Occasionally we used the engine during calms, and all went well until we were pretty well through the Gulf Stream. Even as late as Nov. 10 we swam over the side or hung to the rigging for our morning baths and, except for the fact that our food supply was again nearly exhausted, this part of the cruise was most enjoyable. Instead of putting in at Bermuda, we decided to make for New York and chance it. We laid a course about for Hatteras, assuming that the Gulf Stream would tend to set us north.

All went well until we got about midway between Bermuda and New York on Nov. 15, when a howling northeaster hit us. That afternoon I noticed the masts of a ship ahead of us lifting over the horizon and thought something was coming our way. As we bore down on her she proved to be a three-masted schooner under two jibs and a fully reefed mainsail, pitching a third of her bottom out with each sea and practically hove to. We passed her within 50 yd. to windward, took two photographs and proceeded for New York under full jib and mizzen, much elated over the performance of Typhoon. She was proving herself a regular sea boat.

The Typhoon Receives Two Knockdowns

The second day of the northeaster the Typhoon got her first real knockdown with both mastheads in the water. We were all below except the English youngster, who was at the wheel. The impression I had was that we had been run down. I was in the lee bunk and Dorsett was in the weather bunk on the starboard side. There was a tremendous crash, the cabin was filled with steam from the solid water that came down the Liverpool head; everything on the starboard side, including Dorsett, fell in a direct line and landed on me. I thought that the side of the cabin had come in. Then slowly Typhoon righted herself, due to the 3000 lb. of lead Baldwin had fortunately insisted on placing on the keel in the form of a shoe.

During the night the wind got around to the southwest and increased in intensity, whipping the sea into a mass of confused unstable crests. We had been running under the storm trisail since the night of the first day and as the wind shifted we altered our course so as to run before it. To make steering easier and to prevent broaching-to, we had to put out a long line over the stern and, in an endeavor to hang on to our trisail as long as possible, we put out another line on the end of which was a large iron bucket. But even with this drag astern there was danger of pitch-poling if we ran too squarely before the seas and an equal danger of broaching-to if we took them too broadly over the quarter. I decided that we could not carry the trisail any longer and ordered the crew to bring out the sea anchor which unfortunately was one of those things which had been left unfinished at the start. Most of us have theories about sea anchors and I had taken the precaution to lead the line through a bullnose on the end of the bowsprit so as to get 7-ft. additional leverage to hold her head to the wind. The line was already rove and all that was necessary was to rig the shears in the mouth of the bag, which is 6 ft. square, lash on a pig of lead to keep it submerged and improvise a bridle, and then lower the trisail, luff into the wind and throw the bag over.

I sent Fox forward with instructions to get a life line about him and Dorsett jumped out of the cockpit to assist him in lowering the trisail, when a big sea swept over us, taking my sou'wester and burying Fox to his armpits. Dorsett clung to the mizzen rigging and then started again to claw his way forward along the handrail on the cabin trunk. Then the big crash came. It is not the long swinging regular seas that bother you, the kind we had had for the two preceding days, but the tremendous unstable ones, caused by a sudden change of wind; it was one of these that crashed down upon us, burying us under tons of solid water. I was crouching in the corner of the cockpit with both hands on the wheel and was conscious only of being under solid water. How far over we went I could not tell, but I had a depressed sort of feeling that Typhoon's cruise was over

at last. Then we came up slowly and as the water rolled off of me I looked out to leeward and there, bobbing in an acre of froth, was Jim Dorsett 50 to 60 ft. away from the ship, the air in his yellow oilskins puffing about his shoulders and supporting him. There seemed to be not a ghost of a chance to save him. Fox also had been washed overboard but had got back by way of the mast that had come down on top of him and with admirable presence of mind had lowered the trisail to kill our headway.

I thought of the lines trailing astern and yelled and pointed to them. Dorsett too remembered them, and as we drifted past him under bare poles he struck out and finally got one of them. But our headway was still so great that he was unable to hold on and started sliding down the line; each time he came to the surface he was farther from the ship. Finally he turned on his back and succeeded in hanging on, sort of planing along with his head out of water, and the three of us were able to haul him in under the quarter. As we got him close in he smiled up at us, although half drowned, and said: "Well, fellows, here I am." It was a display of nerve that would have brought tears had we had time for any such emotion. Grabbing him by the oilskins we were unable to lift him aboard, weakened as we were from exertion and from several days' diet of fried flour-paste. As the stern lifted we held him high out of water, only to souse him again when it came down. Finally we pried a leg over the rail with a boathook and I grabbed it and lay down in the waterway, determined that at least we would have a leg. Finally we got him aboard, passed him below and threw over the sea anchor. But as soon as the strain came on the line, it parted and left us in the trough of the sea under bare poles. But we had been in this position for a good 10 min. and nothing had happened, except for the occasional crash of a sea on deck, and so we decided to let her fight it out alone. We went below, opened a bottle of cognac, sang for a while and turned in.

Until I went below, I did not realize just what had happened to us. The floor-boards were up, the heavy slag ballast and in fact everything in the ship seemed to be in a soggy, oily mass on the lee side. The ashes from the stove hit the charts, which were slung up in the intersection of the cabin roof and the side, showing that we had not only been knocked down, but that our masts had been pointing at an angle of practically 120 deg. from the vertical. This all sounds like a very harrowing experience and I am telling it only to prove that a properly designed and built boat will live through anything. The boat is not the determining factor so much as the endurance of the crew.

AT SEA

We experienced no difficulty throughout the night except the occasional crash of a big sea on deck, and the next day the wind had gone down to a wholesale breeze. We semaphored a couple of steamers to report us and one chap, not being able to read our signal, hove-to to find out what the strange apparition might be. He was a Spaniard, and since he was decent enough to heave to, I decided to ask him for some food. We came alongside and I passed up my card on the boathook, explaining our predicament. He sent down his card by the boathook, and then we waited and nothing seemed to happen. Finally a sort of caravan emerged from one of his hatches, bearing bags and boxes of food which the crew started to lower away. I held up my hands and explained that we were merely going into New York and not on our way to Europe, but the good-natured skipper kept on lowering food, laughing and pelting us with canned peaches. When he finished there was enough food aboard the Typhoon to take her back the way she had come. It was just one of those courtesies of the sea that are the rule rather than the exception.

As soon as we could decently do so, after dipping our ensign and waving him a farewell, we went below and ate for the rest of the afternoon. It was the most eventful day of the cruise. Our arrival in New York has already been more than adequately covered by the press and it is needless to speak further of it at this time.

EXPORTS OF MINERAL OIL

THE preliminary report of the Bureau of Foreign and Domestic Commerce for 1920 shows exports from the United States of mineral oil totaling 3,100,509,600 gal., compared with 2,492,754,027 gal. in 1919, an increase of 24.4 per cent. In value these represented $549,348,840 against $343,673,432. A comparison of the value of mineral oil exports with those of other commodities such as cotton, breadstuffs, meat and dairy products and cottonseed oil is given in the table in the next column.

VALUE OF MINERAL OIL EXPORTS

	1920	1919
Cotton	$1,136,408,916	$1,137,371,252
Breadstuffs	1,079,085,838	920,301,977
Mineral oils	549,348,840	343,673,432
Meat and dairy products	544,074,050	1,160,643,133
Cottonseed oil	34,874,790	40,890,268
Total	$3,343,792,434	$3,602,880,062

The exports of crude oil and refined products for the years 1917 to 1920, inclusive, are given in the table below.

EXPORTS OF CRUDE OIL AND REFINED PRODUCTS FROM 1917 TO 1920

	1920	1919	1918	1917
Crude oil, gal.	337,886,081	248,821,453	205,829,030	172,121,195
Illuminating oil, gal.	861,891,942	979,155,147	491,109,815	658,156,487
Lubricating oil, gal.	410,874,209	274,795,166	257,317,253	280,437,663
Gasoline, naphtha, etc., gal.	642,897,428	372,132,957	559,368,855	415,878,844
Fuel and gas oil, gal.	846,959,940	584,849,605	1,200,750,319	1,123,473,047
Residuum, gal.	[1]	32,999,699	244,474	1,051,113
	3,100,509,600	2,492,754,027	2,714,619,746	2,651,118,349

[1]Included with fuel and gas oil.

ELECTROMAGNETIC THEORY

ELECTROMAGNETIC researches are now so comprehensive in their scope that they may be regarded as including, from a broad standpoint, nearly all of the scientific researches comprised within the original meaning of natural philosophy. Chemistry, mechanics, light, heat, and now even gravitation, are claimed as branches of electromagnetics. Perhaps the most recently active field of electromagnetic investigation has been physical chemistry, on the border line of the atomic theory. The interest in atoms has been directed to their constituent electrons. It is curious that the electron, which has been so prominently occupying scientific attention everywhere, is an entity having a mass of less than 10^{27} gram. The number of electrons in a gram of matter is therefore estimated at more than 10^{27}. A convenient method of visualizing a large number of this kind is to consider the size of a cubical box necessary to contain that number of small shot. An ordinary diameter of small bird shot would be 1 mm. On this basis the cubical box that would be necessary to hold 10^{27} shot would be 10^{9} mm., or 10^{6} meters or 10^{3} km., in length of edge. It would be about as long as distance from Norfolk, Va., to Ottawa, Canada. Albeit a gram of matter is supposed to hold that number of electrons, these are not believed to be tightly packed like shot in the hypothetical box. On the contrary, the average distance between adjacent electrons must be very large compared with the dimensions of each electron. The electron is at present the smallest thing known to exist, and is about 50,000 times smaller in "diameter" than the hydrogen atom, which, in its turn, was the smallest thing recognized in science a generation ago.

Since the experimental researches of Millikan have enabled us to study the behavior of individual electrons and to count them one at a time like coins, the belief in the existence and properties of these most minute electrics of the undermicroscopic world has made great advances. Chemical affinities, forces and combinations are assumed to be the stories of the properties and propensities of electrons in their various organized atomic groups.

The recent brilliant investigations of Bragg and Moseley have led to the belief that the 88 known chemical elements, from hydrogen to uranium, occupy a series of simple atomic numbers from 1 to 92 inclusive, with only four missing or unidentified members. To each of these atomic numbers belongs, according to theory, a like number of nucleus electropositive charges and a like number of electronegative electrons.

Langmuir's Postulates Occupy Scientists

A very interesting recent theory of Langmuir deals with the constitution and construction of the various 88 chemical elements. Each kind of atom has a three-dimensional structure, approximately spherical in form. The polar axis of an atom is an axis of symmetry, and the equatorial plane perpendicular thereto is a plane of symmetry. By building up spherical aggregations of one, two, three and four units in radius, with "cells" of equal size apportioned among the different electrons, the theory claims to account for a number of the known chemical properties of the different atoms and to satisfy the periodic series originally pointed out by Mendeléeff.

Langmuir's spherical atoms are actually more easily worked with as cubes. The atoms are chemically inert when the number of electrons is such as form simple staple groupings of positive nuclei and negative electrons evenly divided over the surface. Thus, neon with two electrons and helium with $10 = 2 + 8$, two in the inside and eight in the outside shell, are the first two of the highly inert atoms. When, however, the atomic numbers do not fill up the outside shells forces are exerted on the neighboring atoms to bring about a structural union, or chemical combination, that will complete octet groups of electrons between them. In this manner a very fascinating sterochemistry is worked out for a number of atoms and molecules, which is purely electromagnetic in one aspect, purely chemical in another and purely structural in a third.

The Langmuir theory offers so many opportunities for examination and discussion over an enormous field of bald chemical facts, which have hitherto for the most part defied explanation, that it will take the chemists a long time to come to a decision as to the final place of the theory in the general field. It is difficult to decide at first sight how atoms in a given molecular combination behave toward each other on this electron hypothesis. It is advantageous to construct mechanical models of the various component atoms and to study the ways in which these can be brought into mutual contact, with the maximum stability and structural simplicity. The theory is built upon 11 postulates and offers a new view of chemical valences.

Einstein's Theory Appears Well Founded

Another subject of investigation which has assumed great scientific prominence during the past year is the Einstein theory of relativity in its latest form. Indeed, the interest in this scientific subject may be said to have overshadowed almost all others during recent months. The theory is admitted to involve three consequences, capable of being experimentally verified and not otherwise explainable; namely, first, a slow rotation of a planetary orbit, which in the case of Mercury takes 149 years to advance through 1 min. of arc, or 3,000,000 years to complete one revolution; second, a bending of light in a powerful gravitational field, as though the light were ponderable material, and, third, a minute displacement of the spectral lines of the sun toward the red end of the spectrum. The first two predictions are declared to have been already verified, while the third is still undecided.

As to the consequences of the theory, they may be regarded as at present unrecognizable to the ordinary observer, inappreciable in engineering or geodesy, appreciable in astronomy, but of very great significance in philosophy or the doctrine of the universe. The remarkable fact, from an electromagnetic standpoint, is that the new space geometry, which is no longer simple Euclidium three-dimensional geometry, is claimed to be in complete conformity with the Maxwellian theory of the electromagnetic field. According to this doctrine, space is not definite, but very large and limited; gravitational force is merely a fictional phenomenon, due to our misinterpretation of the vagaries of geometrical space in the vicinity of matter, and time is indissolubly linked with space. While it is not difficult to obtain an abstract comprehension of this doctrine, on the basis of mathematical equations, it is extremely difficult to obtain a concrete comprehension that can be visualized or constructed. It is pointed out, however, by the protagonists of this remarkable theory that we have no right to deny its validity merely because we have difficulty in visualizing it to our untrained senses.—A. E. Kennelly in *Electrical World*.

Instantaneous Current and Voltage Values In a Battery[1]

By G. W. Vinal[2] and C. L. Snyder[3]

Illustrated With Photographs and Charts

FOR some months the Bureau of Standards has been working upon specifications[4] for starting and lighting batteries at the request of the Motor Transport Corps. These specifications have now been completed and will be published as the appendix to a circular to be issued by the Bureau. Various laboratory tests also have been made on batteries of this class. In addition to these tests it seemed desirable to study the performance of the batteries when in actual use on automobiles. Measurements of the current and voltage of the batteries as made by the ordinary indicating instruments do not give accurate or adequate information because of the rapidly fluctuating values of these quantities. We have therefore measured the instantaneous values of current and voltage from oscillograph records. The variations of voltage and current when the engine is operated by the starter, and the variation of charging current through the battery under running conditions, are shown in the oscillograms that follow.

In the course of the experiments additional information was obtained with respect to the operation of the starter system and the engine itself. It is intended to point out in this paper some of the effects relating to temperature, compression, lubrication, distributor action and flywheel velocity, in addition to the battery characteristics. The results which are given are suggestive only of the possible application of this method for the study of the performance of starter systems and internal-combustion engines. It is believed that a development of this method will provide an easy and exact method for studying the operation of the various parts. This method was found entirely satisfactory for studying the problems connected with the battery.

Experiments have been made on a number of different cars but the most systematic and comprehensive series of measurements were made on a Dodge car which has been driven about 15,000 miles and a Cadillac car, which has been driven 18,000 miles. Most of the curves used as illustrations in this paper were obtained from these cars. All of the cars tested were in ordinary running order.

Methods and Apparatus.

The instantaneous values of current and voltage were obtained by a three-element moving-coil type oscillograph. To obtain records for periods of long duration, the ordinary film drum was replaced by a camera of special construction in which bromide paper in rolls 100 ft. long was used. When making a record, the sensitized paper was wound upon a drum in the lower end of the camera after having passed the oscillograph slot through which the recording images were projected. One of the elements was used to record the voltage at the terminals of the battery,

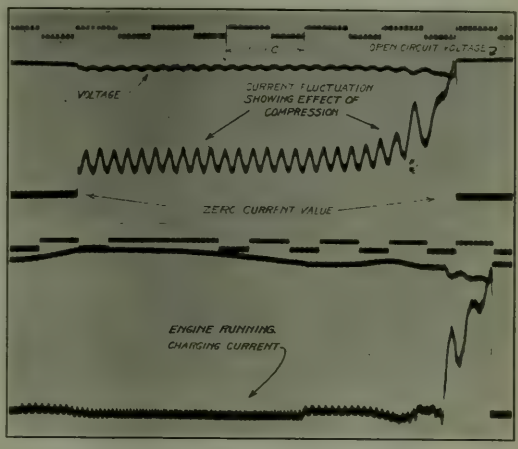


Fig. 1—Record of Current and Voltage in the Battery Circuit of a Dodge Car (Above) when the Starter Was Cranking the Engine without Ignition and (Below) when the Engine Was Running

another the current through the battery circuit, and the third the time record, which consisted of the ½-sec. ticks of a chronometer.

The camera was arranged so that the photographic paper moved at a uniform speed, irrespective of the amount of paper remaining in the camera. It was possible, however, to change the speed of the paper at will. Some of the records have been made with the paper moving at low speeds, about 2 cm. (0.787 in.) per sec., others at an intermediate speed of 3½ cm. (1.378 in.) per sec., but most of them at high speed, 7½ cm. (2.953 in.) per sec.

To measure the current through the battery circuit, a shunt of 0.006 ohm. resistance was inserted in the circuit at the battery. Potential wires from this shunt were connected with the current element in the oscillograph. Measurements of the current and voltage were made simultaneously by an ammeter and a voltmeter. These meters have too slow a period to give the initial values but the readings gave satisfactory average values for the current and voltage when the starter was operated at a uniform rate. Such readings were used as a check upon the calibration of the elements in the oscillograph. The deflections of the elements are approximately proportional to the current or voltage measured. In some cases, however, a deviation was found, which may have been due to the slight tension of the element. The tension was necessarily reduced to a minimum to give sufficient deflection. It was found necessary to calibrate the current and voltage elements with steady currents and voltages which could be accurately measured. This calibration

[1] Published by permission of the Director of the Bureau of Standards, Washington.
[2] Physicist, Bureau of Standards, Washington.
[3] Assistant physicist, Bureau of Standards, Washington.
[4] See The Journal, December, 1920, p. 559.

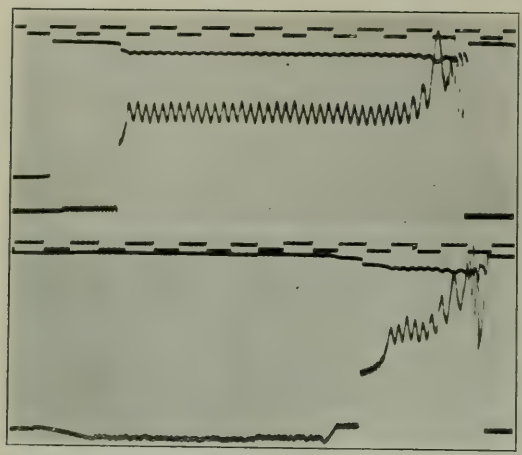


FIG. 2—RECORD OF CURRENT AND VOLTAGE IN THE BATTERY CIRCUIT OF A FORD CAR OPERATED (ABOVE) WITHOUT THE IGNITION AND (BELOW) WITH THE ENGINE RUNNING

was necessarily repeated each time the tension of any element was altered, or when the gold fuses were replaced. It will be noticed that the ½-sec. ticks of the time record are unequal. This was due to the action of the relay in the circuit. From the beginning of one second to the beginning of the next can, however, be considered as 1 sec. to a very high degree of accuracy.

VARIATIONS IN VOLTAGE AND CURRENT.

The general character of the curves obtained is shown in the following figures. All of these oscillograms begin at the right and are therefore to be read from right to left. A more detailed examination of these and similar figures will be given in the later sections. The upper portion of Fig. 1 shows curves for the Dodge car, equipped with Northeast starter system, Model D, and Willard battery, type SJR-26. The time intervals are recorded at the top of the record. The two curves below represent the fluctuations of the voltage and current of the battery when the starter is in operation. The successive peaks of the latter show the increase of current for each compressive stroke. The lower half of this illustration shows the operation of the same system with the ignition. It will be seen from the curve that the engine started on the second compression, somewhat less than 1 sec. after the starter-switch was closed. The variations in the current curve will be explained later. Fig. 2 shows similar observations made on a 1920 Ford car that had run 5000 miles. The initial current values of both portions of this illustration are beyond the limits of the paper. During the first half second the current fluctuated violently between 200 and 300 amp. In the upper portion of Fig. 2 it will be seen that the minimum voltage values correspond with the maximum current values. This is true of the other illustrations also, but in most of them it is not as clearly seen as here. The engine was started with the ignition on the battery in the lower portion of this illustration. The discontinuous point in the current curve shows the time at which the starter-pedal was released. A corresponding rise in the voltage is to be observed. Fig 3 was obtained on a Chalmers car (35A, 1917 model) which had been driven 12,000 miles. The characteristics shown are somewhat similar to those in Fig. 2. Fig. 4 was obtained on a four-cylinder Studebaker car that had been driven 20,000 miles. These curves are without the violent fluctuations observed during the first half second in the case of the two preceding illustrations. Fig. 5 shows curves for the eight-cylinder Cadillac car. The initial current was approximately 410 amp., decreasing to an average running value of about 150 amp. as shown in the upper section. In the lower portion the ignition

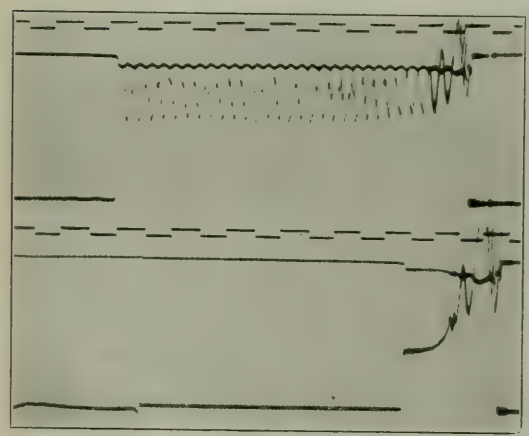


FIG. 3—RECORD OF CURRENT AND VOLTAGE IN THE BATTERY CIRCUIT OF A CHALMERS CAR OPERATED (ABOVE) WITHOUT THE IGNITION AND (BELOW) WITH THE IGNITION

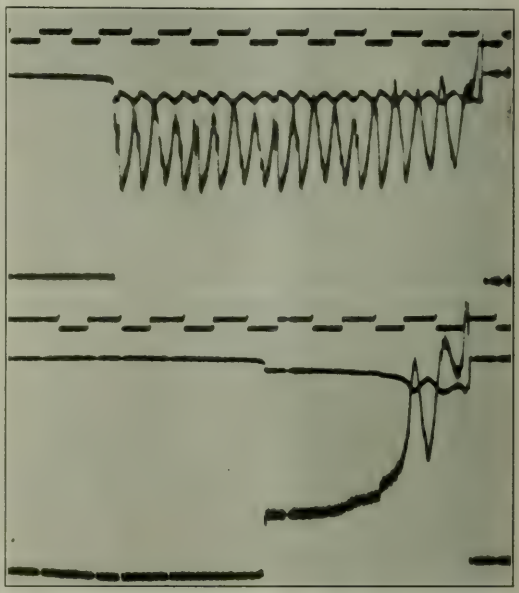


FIG. 4—RECORD OF CURRENT AND VOLTAGE IN THE BATTERY CIRCUIT OF A STUDEBAKER CAR OPERATED (ABOVE) WITHOUT THE IGNITION AND (BELOW) WITH THE IGNITION

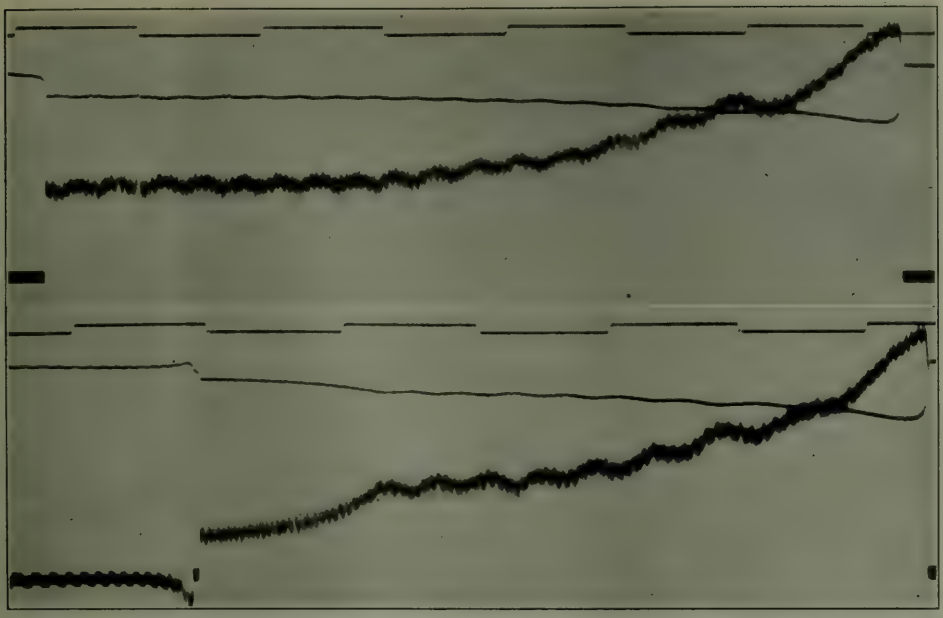


Fig. 5—Record of Current and Voltage in the Battery Circuit of a Cadillac Car (Above) as the Starter Cranks the Engine without the Ignition and (Below) with the Ignition

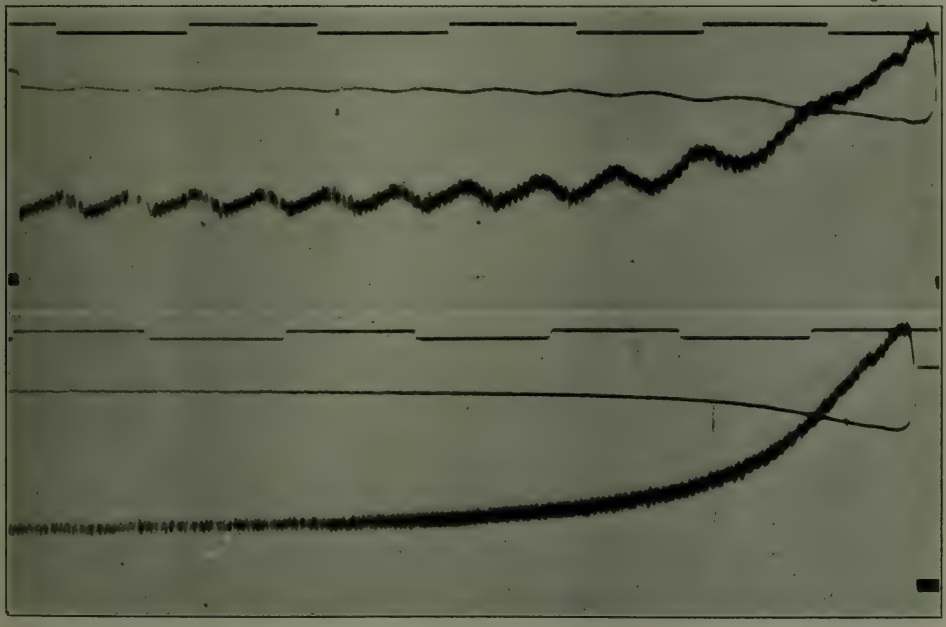


Fig. 6—Current and Voltage Curves Obtained from a Cadillac Car (Above) When All the Spark-Plugs Were Removed from One Bank of the Engine and (Below) When the Spark-Plugs Were Entirely Removed from the Engine

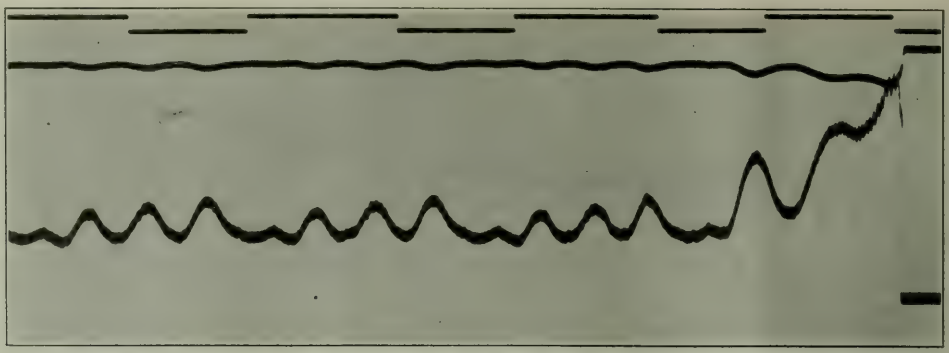


FIG. 7—RECORD OBTAINED AFTER A PET COCK HAD BEEN REMOVED FROM ONE CYLINDER OF A DODGE CAR TO SHOW THE EFFECT OF COMPRESSION ON THE CURRENT AND VOLTAGE OF THE BATTERY

switch was closed and the engine started at the end of 2¼ sec.

In the illustrations for the various cars characteristic differences are evident in the current and voltage curves. A comparison of these curves shown in the upper part of Figs. 1, 2, 3, 4 and 5 indicates that some are more nearly sine curves than others. These differences are probably characteristic of differences in the design of the engines. By making an harmonic analysis of such curves it might be possible to trace the effects of the timing of the valves and other factors. For such an analysis it would be desirable to increase the time scale as has been done in Fig. 6, but we have not attempted such an harmonic analysis in this paper. The lower sets of curves in Figs. 1 to 5 inclusive show characteristic differences in the starter systems, particularly between the single and two-unit systems.

The sensibility of the oscillograph was not the same for all of the measurements, and some differences in the appearance of the curves have been caused by variations in the intensity and width of the beam of light. The cars were all in ordinary running condition.

EFFECT OF TEMPERATURE.

Fig. 6 shows the effect of the temperature of the engine on the current and voltage required for starting. The engine was operated by the starter without ignition. These curves were obtained on the Dodge car at radiator temperatures of 20, 50 and 77 deg. cent. (68, 122 and 171 fahr.) respectively. The initial values for current and voltage have been read from these curves and tabulated in Table 1, together with the values obtained when the speed was constant. The average operating values of the current and voltage at a constant speed as read from the curves agree closely with the values given by the indicating instruments in the circuit. The difference between the maximum and minimum values at a constant speed is the amplitude given in the table. It will be seen by comparing the results for the Dodge car at 20 deg. cent. (68 deg. fahr.) with those at higher temperatures that the initial starting current does not decrease in the same proportion as the operating current, when the temperature is increased. This indicates that the initial current which the battery must supply depends more upon the inertia of the system than upon the temperature of the engine. The average operating current at 50 deg. cent. (122 deg. fahr.) is practically the same as the current at 77 deg. cent. (171 deg. fahr.). A change is to be noted, however, in the amplitude of the fluctuations. At 20 deg. cent. (68 deg. fahr.) the amplitude is 36 amp., at 50 deg. cent. (122 deg. fahr.) 28 amp. and at 77 deg. cent. (171 deg. fahr.) 16 amp. The significance of these changes will be brought out more clearly later on. Upon examination of these curves with reference to the time scale, it will be seen that the speed of the engine can be computed easily since there are two compressions for each revolution of the crankshaft. The values for the Cadillac car given in Table 1 have been computed from 11 oscillograms which are not shown as illustrations. The power required initially to start the system in motion and the

TABLE 1—INSTANTANEOUS AND AVERAGE VALUES OF CURRENT AND VOLTAGE FOR AUTOMOBILE BATTERIES

Car	Temperature of Radiator Water		Engine Speed, R.P.M.	Throttle	Initial Values		Average Operating Values		Amplitude of Current, Amp.	Power Required, Watts	
	deg. cent.	deg. fahr.			Current, Amp.	Voltage	Current Amp.	Voltage		Initial	Average Operating
Dodge	20	68	116.8	Closed	136	10.30	62	11.10	36	1,400	688
Dodge	50	122	162.6	Closed	127	11.10	38	11.80	28	1.410	449
Dodge	77	171	150.9	Closed	117	11.10	40	11.80	18	1.300	472
Cadillac	25	77	89.0	Closed[5]	455	4.64	133	5.61	..	2.110	746
Cadillac	25	77	90.0	Open[5]	449	4.62	137	5.62	..	2.073	770
Cadillac	35	95	91.6	Closed	400	4.57	136	5.38	..	1,826	732
Cadillac	35	95	94.6	Open[5]	409	4.44	140	5.36	..	1.814	752
Cadillac	65	149	93.7	Open[5]	417	4.46	138	5.37	..	1.860	742
Cadillac	69	156	100.0	Closed	432	4.56	148	5.40	..	1,984	800
Cadillac	82	180	96.0	Open	417	4.42	154	5.38	..	1,842	829

[5] Results given are the mean of two determinations.

average operating power when the speed was constant show little change due to temperature above 35 deg. cent. (95 deg. fahr.). It will be noticed in the table that slightly more power is required initially to start the system when the throttle is closed, but that the average operating power is less if the speed remains constant. The latter result may be due to effects produced by the greater compression in the cylinders when the throttle is open. As these observations were made in the summer, it was not convenient to obtain temperatures below those given in the table. The power required to overcome the inertia of the system is somewhat less than the lowest figure given in next to the last column of Table 1. The power required to overcome the compression is practically constant irrespective of the temperature, provided the throttle opening is fixed. The power to overcome friction would probably increase rapidly at temperatures below those recorded here, as is indicated by the upper portion of Fig. 6. The increase in average operating power required for the Cadillac at the highest temperatures suggests increased friction. The engine had been run for a considerable period of time to increase the temperature. The oil and bearings had become heated and it is probable that the bearings were tighter at the higher temperatures because the engine had just been overhauled. Similar effects might be produced by insufficient lubrication at these temperatures.

Effect of Compression and Lubrication

To demonstrate clearly that the fluctuations in the current curve are due to compression in the cylinders, a run was made in which one priming-cup was removed.

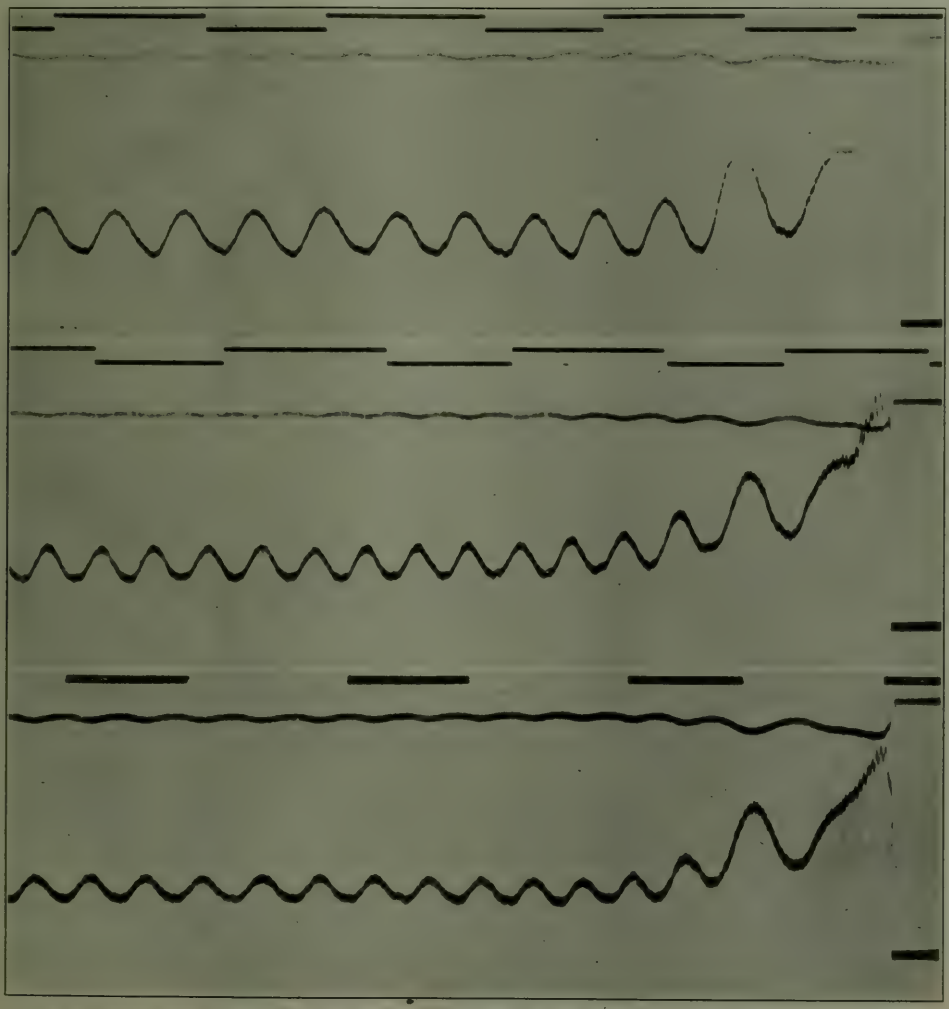


Fig. 8—Record from a Dodge Car Obtained with Radiator Temperatures of 20 Deg. Cent. (68 Deg. Fahr.), 50 Deg. Cent. (122 Deg. Fahr.) and 77 Deg. Cent. (171 Deg. Fahr.)

The results of this experiment on the Dodge car are shown in Fig. 7. This illustration shows that there was only a slight compression in the cylinder that was open.

The power furnished by the battery is expended in several ways. A small part is used up within the starter itself. This can be measured as in the case of any electric motor. A second part is expended in compressing the gas within the cylinders. A third part is expended in overcoming friction in the engine and varies with the speed and the lubrication. A fourth part is used for ignition on some cars. The amount of power which the battery furnishes can be obtained for any instant by multiplying the instantaneous values of current and voltage. If this product is multiplied by an increment of time we obtain the total energy, or work done by the battery during this instant of time.

It is evident, therefore, that careful measurements of the electric power and time can furnish information as to the amount of work being done by the battery during any part of a cycle. One significant result of this can be seen in Fig. 7, where it will be observed that the engine speeds up in passing what would have been the compression stroke of the cylinder had the priming-cup not been removed. As there was no compression in this cylinder, no energy could be returned to the system by compressed gas. The increased time required to reach the next maximum shows that the engine decreased in speed. This fact is determined by measuring the distance between the successive maximum values of the curve. A rolling effect results which can be noticed by the difference in height of the successive maximum values. The watts delivered by the battery can be used as a sensitive and exact method of determining the instantaneous speed of the flywheel. The greater the inertia of the flywheel the smaller will be the fluctuations of the current and voltage curves.

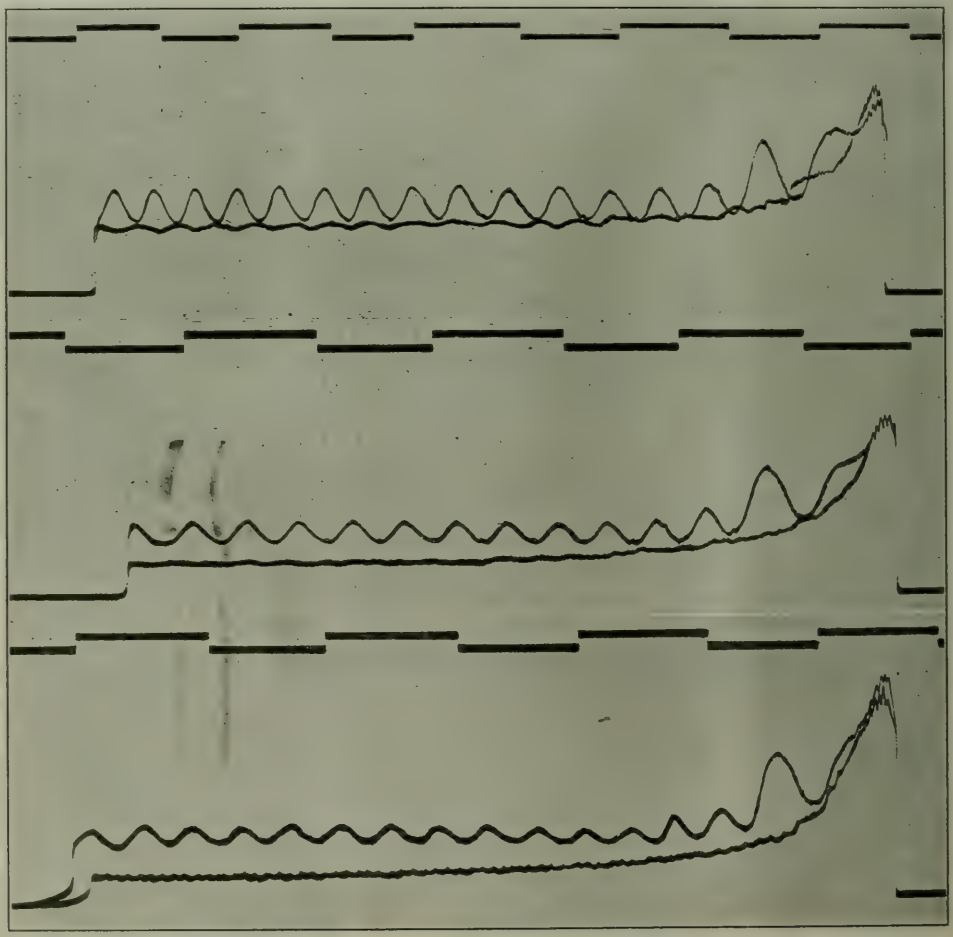


FIG. 9—REMOVING ALL THE SPARK-PLUGS IN A DODGE CAR ELIMINATED TO A GREAT EXTENT THE FLUCTUATIONS IN THE CURRENT CURVE OF THE BATTERY

The Radiator Temperatures at Which These Curves Were Obtained Were 20 Deg. Cent. (68 Deg. Fahr.), 47 Deg. Cent. (117 Deg. Fahr.) and 84 Deg. Cent. (183 Deg. Fahr.)

The curves of Fig. 8 (Dodge car) show a decreased amplitude at the higher temperatures. This suggests the conclusion that the amplitude for this type of engine depends on lubrication as well as compression. The effect due to friction is least at the top and bottom of the stroke and greatest when the crank arm and the connecting rod are at right angles. This result has been confirmed by experiments, using one bank of the Cadillac engine.

It is possible to separate the effect of compression from that of friction and other losses, by relieving the compression in all of the cylinders. This might best be done by removing the head of the engine, but in these experiments the compression was more conveniently relieved by removing the spark-plugs. A series of comparative measurements, the results of which are shown in Fig. 9, were made on the Dodge car at three different radiator temperatures, 20, 47 and 84 deg. cent. (68.0 116.6 and 183.2 deg. fahr.), respectively. These figures

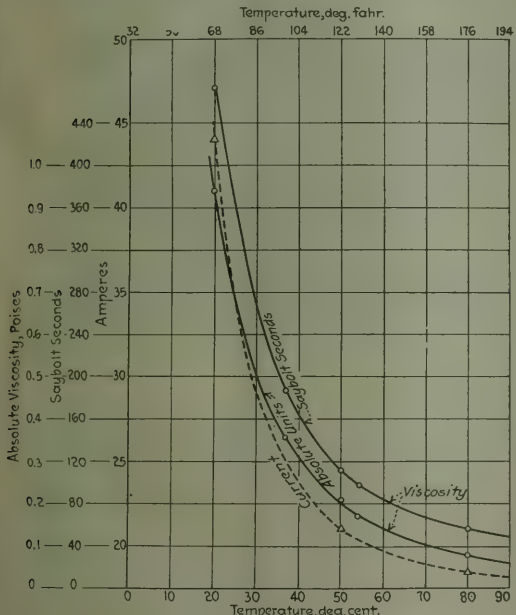


FIG. 10—RELATION OF THE ELECTRIC CURRENT IN THE STARTER CIRCUIT TO THE VISCOSITY OF THE OIL USED IN THE ENGINE
The Current Values Were Those Given by the Curves in Fig. 9 and Are Plotted against the Temperature

show that the curves obtained when the spark-plugs were removed are devoid of the marked fluctuations of current observed when the spark-plugs were in place. At each temperature a record of the current values was made with the spark-plugs in, followed by an exactly similar measurement with the spark-plugs removed. The corresponding curves for each temperature have been superposed and traced together in Fig. 9, care being taken to make them in perfect register, as to the beginning of the curves and their position with respect to the horizontal axis. The results obtained at 20 deg. cent. (68 deg. fahr.) show that the curve without compression is practically tangent to the lower values of

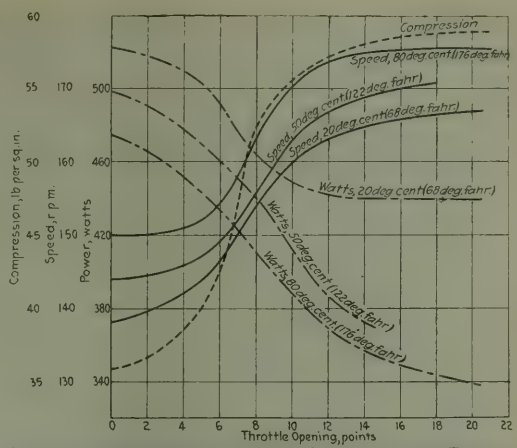

Compression, lb. per sq. in.
Speed, r.p.m.
Power, watts
Throttle Opening, points
Compression
Speed, 80 deg. cent. (176 deg. fahr.)
Speed, 50 deg. cent. (122 deg. fahr.)
Speed, 20 deg. cent. (68 deg. fahr.)
Watts, 20 deg. cent. (68 deg. fahr.)
Watts, 50 deg. cent. (122 deg. fahr.)
Watts, 80 deg. cent. (176 deg. fahr.)

FIG. 11—RELATION BETWEEN THROTTLE OPENING AND THE ELECTRIC POWER IN WATTS DELIVERED BY THE BATTERY OF A DODGE CAR IN CRANKING THE ENGINE AT TEMPERATURES OF 20, 50 AND 80 DEG. CENT. (68, 122 AND 176 DEG. FAHR.)

current when the spark-plugs are in position. At the higher temperatures this curve falls somewhat below the minimum current values. The upper portion of Fig. 6 shows the results of an experiment on the Cadillac car with the spark-plugs removed from the left bank. By comparing this with the upper section of Fig. 5, the overlapping effect of the cylinders can be seen. The lower half of Fig. 6 shows the results of an experiment on the Cadillac car in which all spark-plugs had been removed. The same high value of the initial current is

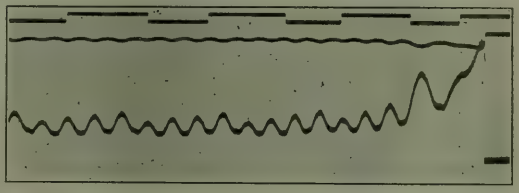


FIG. 12—EFFECT OF A PARTLY OPENED VALVE IN ONE CYLINDER OF A DODGE CAR ON THE CURRENT CURVE WITH THE IGNITION OFF

to be noted here as in the upper portion of Figs. 5 and 6. If the two sections of Fig. 6 were superposed, the current curve of the lower portion would be tangent to the bottom of the current curve of the upper section.

One of the curves given in Fig. 10 shows the relation

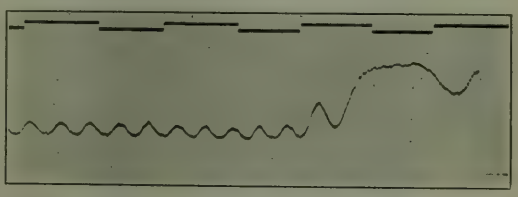


FIG. 13—A STICKING OF THE ENGINE AFTER DRAWING AIR DIRECTLY INTO THE CYLINDERS OF A DODGE CAR IS SHOWN IN THIS CURRENT CURVE
The Record Was Obtained at a Temperature of 47 Deg. Cent (117 Deg. Fahr.) after the Spark-Plugs Had Been Replaced.

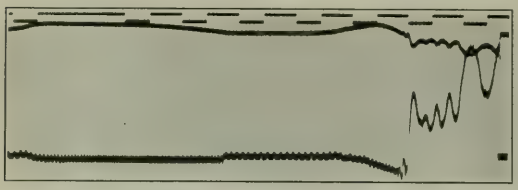


FIG. 14—STICKING OF THE ENGINE ALSO RESULTED AFTER THE PET COCK HAD BEEN REPLACED

between the temperature and viscosity of the oil used in this particular Dodge car. The other curve gives the relation between the temperature and current values used in turning the engine after the inertia of the system had been overcome. These are plotted to a purely arbitrary scale. The marked similarity between these two curves would suggest a decrease in friction with increasing temperature. These curves show that a proportionality exists between the viscosity of the oil and the power required to turn the engine.

A number of experiments were made on the Dodge car at temperatures of 20, 50 and 80 deg. cent. (68, 122 and 176 deg. fahr.) to determine the power consumed by the starter system for various throttle-openings. In Fig. 11 we have plotted the values read from the oscillograms for power and engine speed plotted against an arbitrary scale of throttle-openings. We have also plotted the compression curve as measured by a gage for the same throttle-openings as well as these could be determined without the use of fixed orifices in the carbureter.

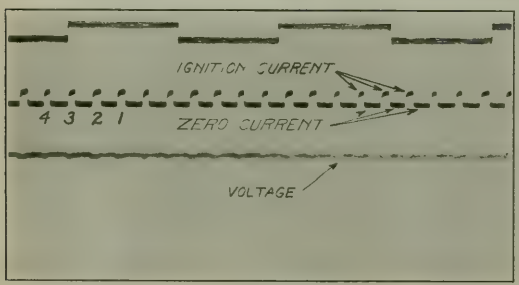


FIG. 16—THE IGNITION CURRENT WHEN THE ENGINE OF A DODGE CAR WAS RUNNING SLOWLY

It appears that if the amount of energy lost in the starter itself is known and deducted, and the compressive measurements of the lubricating properties of diffsion released by removing the spark-plugs or the head of the engine, the electrical power necessary to overcome friction can be calculated. In this way, comparaferent oils and friction losses in various parts of the machine might be made under running conditions.

At this point it may be interesting to examine a curve which was obtained when one of the four cylinders of the Dodge car was leaking. The exact cause of the leak is not known, but is supposed to have been due to a particle of carbon lodged in an exhaust valve. A curve showing the result is given in Fig. 12, in which it will be noticed that every fourth maximum is considerably lower than the others.

One peculiar phenomenon was observed in the experiment with the spark-plugs out. It was found that in some cases where air was drawn directly into the cylinder, either by removing the spark-plugs or taking out

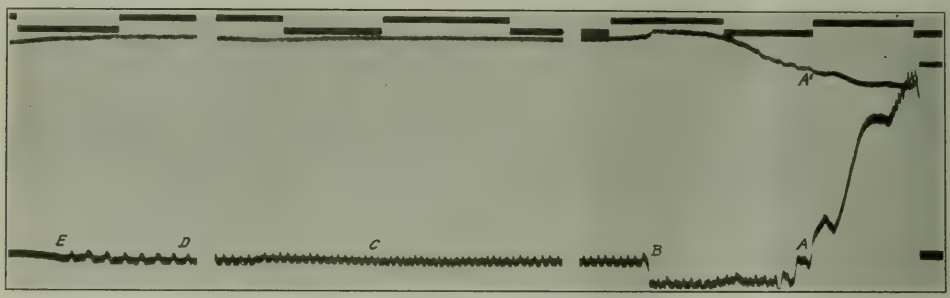


FIG. 15—CURVE SHOWING THE STARTING OF THE DODGE ENGINE ON THE SECOND COMPRESSION AND THE CHARACTERISTICS OF THE CHARGING [illegible]

the priming-cups, greater demands were made upon the battery to operate the starter after the spark-plugs had been replaced. That is to say, more work was required to turn the engine over. In Fig. 13, this effect is shown by the shape of the current curve. This record was made with a radiator temperature of 47 deg. cent. (116.6 deg. fahr.) immediately after the spark-plugs had been replaced. The curve shows the initial effort of the battery to have been exceeded by a second maximum which lasted for more than ½ sec., during which the engine did not turn. After gradually passing this maximum the normal operation was restored. The same phenomenon is observable in another curve, Fig. 14, which was made immediately after an experiment in which a priming-cup was removed from one cylinder. Here again it is seen that the first compression stroke, that of the cylinder from which the priming-cup had been removed and replaced, required as much power as was initially expended by the battery in starting the system in motion. The gas which was contained in the cylinder at this time was of course expelled by the succeeding stroke, but an excessive power consumption was again observed on the next compression in this cylinder, as shown by the fourth maximum. The ignition-switch was on during this experiment and the engine began to operate on the next stroke; hence, it is not possible to tell whether this effect persisted. The cause of this peculiar characteristic is not known.

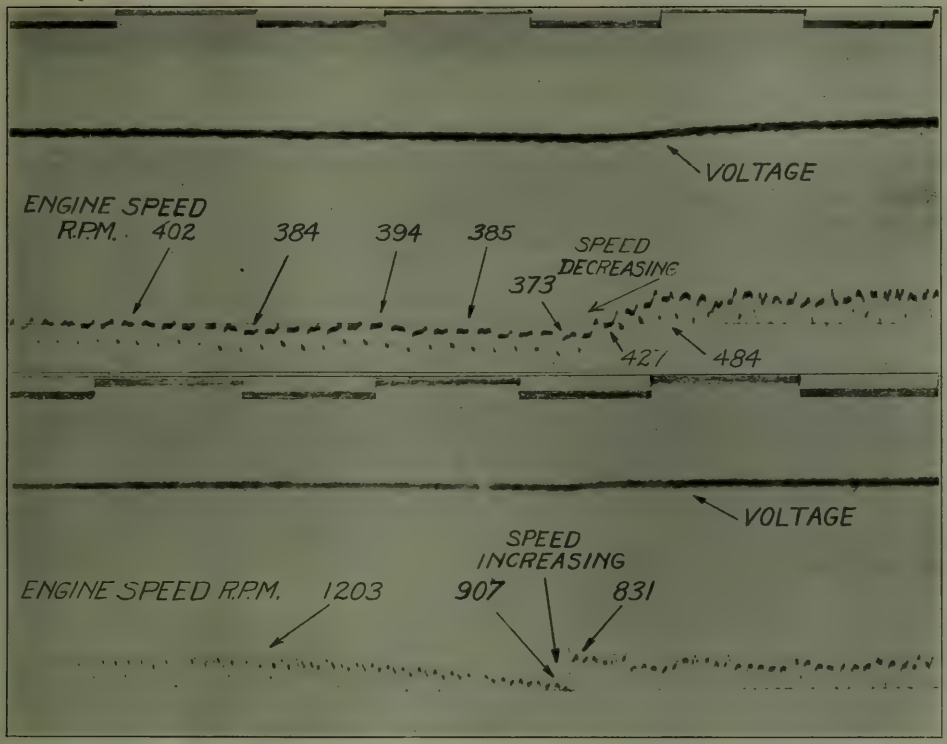


FIG. 17—VARIATION IN THE CHARGING CURRENT DUE TO CHANGING ENGINE SPEED
The Upper Curves Were Obtained at a Lower Speed Than Those Underneath

CHARACTERISTICS WITH THE IGNITION ON

Experiments upon the Dodge car similar to those shown in Fig. 8 have been made with the ignition on. One of the curves which has been thus obtained is shown in Fig. 15. Here the initial value of the current was 136 amp., which is exactly equal to that of the corresponding curve in the top portion of Fig. 8. Also the initial value of the voltage, 10.3, is the same. The engine started on the second compression and the current values fell below the initial line, which indicates that the battery was being charged. An immediate rise in the voltage curve to a point above open-circuit voltage shows this to be true. At the point *A* on the voltage curve is a short horizontal region where it is probable that the reverse-current-relay operated. The charging voltage rises to 2.7 per cell or 16.4 for the battery as a whole. This high-charging voltage was due to the high rate at which the battery was being charged during the time that the starter-switch was still closed. At the point *B*, the starter-switch was released. An immediate decrease in the charging voltage and the charging current is observed. The charging current is seen to have decreased at regular intervals, the spacing of which varies with the speed of the engine. The engine was racing at *C* and slowed down at *D*. The ignition was cut off at *E*. It will be noted that these fluctuations in the charging current ceased at the time the ignition was cut off. Further study to determine the cause of these fluctuations showed that they occur every time the circuit is made through the primary coil of the ignition system. A magnification of these current fluctuations is shown in Fig. 16. Here it will be seen that the duration of time that the current flowed through the primary coil was appreciably longer in the case of the contacts marked 1 and 2 than for those marked 3 and 4. This inequality in the action of the contact points is probably due to inequalities in the cam which operates the contact points or possibly to wear in the distributor camshaft bearings. By comparing Fig. 16 with the lower portion of Fig. 5, it will be seen that the shape of the fluctuations in the current charging curves is materially different in the case of the Dodge and the Cadillac cars, although both have Delco systems for ignition. The difference is explained by the difference in the cams in the distributors.

Since the current passes through the primary of the ignition coil twice for each revolution of the crankshaft of the Dodge car, it is possible to determine the exact speed of the engine by measuring the distance between any given number of these points in the charging curve with respect to the time scale. This is possible for the Cadillac car also, for which there are four contacts for each revolution. The exactness with which the speed of rotation can be measured by this method affords the possibility of determining small changes in the velocity

(*Concluded on page* 364)

The Carburetion of Alcohol

By A. W. Scarratt[1]

Columbus Farm Power Meeting Paper *Illustrated with* Charts

WE are all very familiar with the demands of the automotive industry upon the petroleum resources of this country, and also the rest of the world, and we know the effect which this demand has had upon the characteristics of the fuels commonly used in automotive work. The continued rise and spread of the range of temperatures required to vaporize these fuels have caused engineers, manufacturers and the public an untold amount of worry, grief and expense, not only from the standpoints of design, production, cost and operation, but in connection with increased fuel and lubricating oil consumption and increased repair bills of all kinds that can be traced back to the fuel problem. But the greatest effect which this abnormal demand has created is reflected in the price per gallon of gasoline which in the United States has quadrupled in the past 10 years.

The ever-increasing demand for cars, trucks and tractors in this country has been accompanied by a continual advance of the power farming idea in foreign countries, with a resultant foreign demand for American farm-power equipment. Several of the larger tractor building companies are enjoying a healthy and continually increasing export business, which can be cultivated and brought up to almost unlimited proportions provided the builder will produce tractors of proper design and construction to meet the farming conditions and operating requirements as they prevail, and at a price which makes it possible for the foreign customer to buy. In general, the size and construction of the first-class American tractors are satisfactory. The greatest obstacle confronting most of them is the use of foreign fuels in an economical and satisfactory manner. Cuba, Brazil, Argentina, Chile, Porto Rico and Venezuela are fertile fields for the American tractor and lie at our door, so to speak, but in these countries petroleum fuels are very expensive; while, on the other hand, alcohol, which is produced in vast quantities, is very cheap by comparison. Naturally, if American tractors are to succeed in these countries they must be equipped to operate on alcohol in an economical and efficient manner. Many manufacturers claim that their engines will operate on alcohol, and they will, but in a very inefficient and wasteful manner because they are not primarily designed with a view to using alcohol as a fuel.

Developing an Alcohol Tractor Engine

We have notions as to what should be done to an engine in order that it will operate on alcohol but few of us have had to put our ideas to work and prove them in the dynamometer room and in the field. The Minneapolis Steel & Machinery Co. has exported a large number of tractors in the past 12 years, during which time many of them have been required to operate on alcohol. But it is only in the last two years that the demand for greater economy and efficiency when using alcohol has been seriously felt. During 1920 we conducted some intensive studies and experimental work in the development of an engine that will burn alcohol economically and efficiently and I shall endeavor to acquaint you with a few of the fundamental requirements and with the results to be attained by their use.

Alcohol is difficult to vaporize, and hence difficult to start on. It ignites at a considerably higher temperature than gasoline, is only six-tenths as rich in heat units as gasoline by weight and 15 to 20 per cent heavier by volume. Commercial alcohol contains approximately 10 per cent of water by weight and from 10,000 to 12,000 B.t.u. per lb. Its specific gravity is from 0.80 to 0.84 at 60 deg. fahr.; its range of distillation temperatures is from 158 to 175 deg. fahr. It is a vegetable derivative. These physical characteristics are of course materially different from those of the common petroleum fuels.

We knew that higher compression was necessary, but, as engine size and design influence operation to a large extent, our first problem was to establish an approximately satisfactory compression pressure from which to start our experiments.

Our first trials were with 127-lb. gage compression at a normal operating speed.

The next problem was to determine what amount of heat applied to the mixture is desirable and its general effect on economy, output and operation. We had a real surprise when we found that more heat is needed for good operation on alcohol than is required for using kerosene.

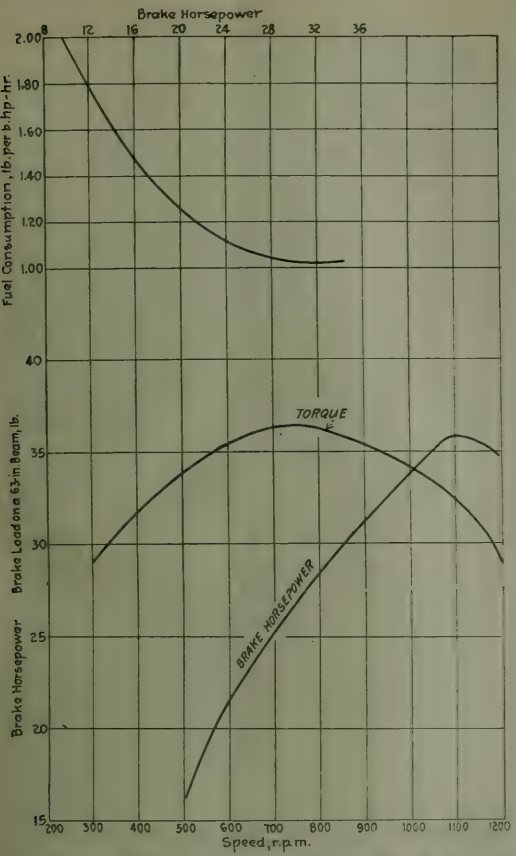
Our next concern was with the power output. This we found was equal to the power developed when using good kerosene. We then devoted ourselves to the general operation of the engine and finally the fuel consumption. At first the operation was not good at low engine speeds under sustained load and the fuel consumption was higher than we liked, but by perseverance and patience we overcame these obstacles and produced very reputable characteristics with good economy and excellent operation, using two distinct and totally different types of carbureting and manifold systems; one of which was the special Twin City Holley system worked out by our company and employed on all Twin City tractors at the present time and the other the Twin City vaporizer system which I described briefly at Ottawa Beach last summer.

As stated before, the heat value of alcohol is only 60 per cent of that of gasoline, it contains 10 per cent of water by weight, it is difficult to vaporize and requires a higher compression pressure which results in increased mechanical friction in the engine. We therefore felt that if we could obtain the same power with alcohol as with gasoline or kerosene for the same expenditure in British thermal units of fuel, we would be doing very well. As a matter of fact, we have actually attained a fair increase in thermal efficiency.

Experimental Work

Our experimental work was done on a 4¼ x 6-in four-cylinder 16-valve engine. At first no heat was applied to

[1]M. S. A. E.—Automotive engineer, Minneapolis Steel & Machinery Co., Minneapolis.

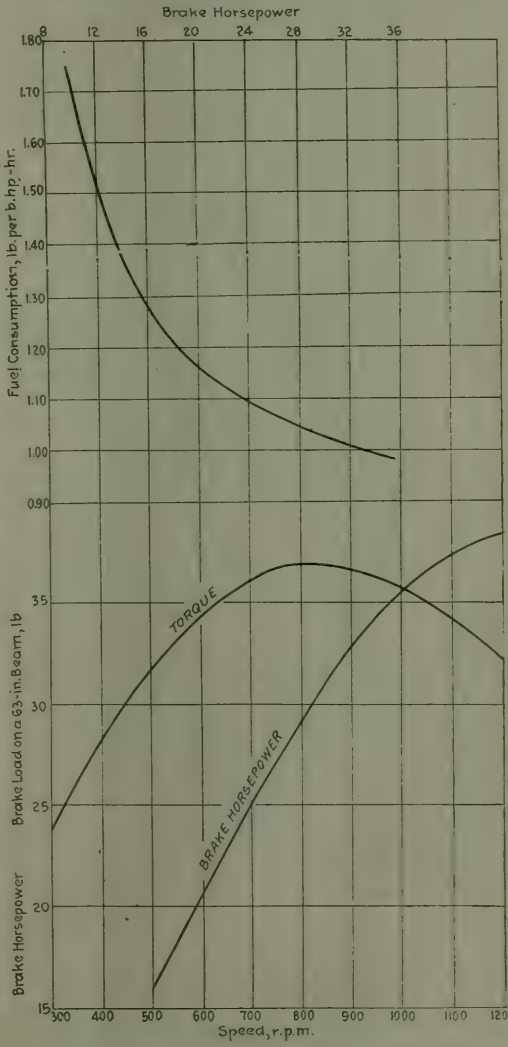

Brake Horsepower
8 12 16 20 24 28 32 36
2.00 1.80 1.60 1.40 1.20 1.00
Fuel Consumption, lb. per b.hp.-hr.
40 35 30 25 20 15
Brake Load on a 63-in. Beam, lb.
Brake Horsepower
TORQUE
BRAKE HORSEPOWER
200 300 400 500 600 700 800 900 1000 1100 1200
Speed, r.p.m.

CHARACTERISTIC CURVES OF A FOUR-CYLINDER ENGINE EQUIPPED WITH A SPECIAL HOT-SPOT MANIFOLD FOR BURNING ALCOHOL

the intake manifold and we were able to develop only 29 b.hp. at 1000 r.p.m., using 127-lb. gage compression, whereas we could easily develop 35 hp. with kerosene, using 63-lb. compression. When running with a cold manifold the temperature of the intake charge dropped to 35 deg. fahr., frost collected on the manifold and water froze on certain portions of it. It was necessary to choke the carbureter to a considerable extent and very unsatisfactory operation was the result. We then applied heat with the result that the horsepower increased from 29 to 35 and operation was very much improved, although the engine would not pick up its load at low speeds.

An intake manifold with glass inserts that was used showed that a large amount of unvaporized fuel was going into the engine. We then increased the heat still more by connecting two air-heaters for the carbureter intake in series. This dried out the mixture but reduced the horsepower from 35 to 33, although the fuel consumption was decreased 1 lb. per b.hp-hr. With this set-up the inlet air to the carbureter reached a temperature of 210 deg. fahr., but after being carbureted the intake gas temperature dropped to 138 deg. fahr. with an exhaust gas temperature of 215 deg. fahr. We then decided to drop the compression pressure to 100 lb., with the result that nearly equal horsepower was developed, the fuel consumption was not increased and the operation was improved at low engine speeds.

We then tried an intermediate compression, using 110 lb., which was finally adopted as giving the most satisfactory results. With this compression we had no difficulty in obtaining an output of 35 hp., which was equal to the power developed when using kerosene. The fuel consumption at maximum load remained at 1 lb. per b.hp.-hr. The alcohol used in this experimental work contained 10,500 B.t.u. per lb. We therefore consumed 10,500 B.t.u. per b.hp-hr., which, if transposed into an equivalent gasoline consumption by weight, would show a fuel consumption of approximately 0.55 lb. per b.hp-hr.,


Brake Horsepower
8 12 16 20 24 28 32 36
1.80 1.70 1.60 1.50 1.40 1.30 1.20 1.10 1.00 0.90
Fuel Consumption, lb. per b.hp.-hr.
35 30 25 20 15
Brake Load on a 63-in. Beam, lb
Brake Horsepower
TORQUE
BRAKE HORSEPOWER
300 400 500 600 700 800 900 1000 1100 1200
Speed, r.p.m.

CHARACTERISTIC CURVES OBTAINED WITH THE SAME ENGINE WITHOUT A SPECIAL HOT-SPOT MANIFOLD

which is exactly equal to the finest performance we have obtained with this engine using gasoline and is decidedly more economical than average engine performance indicates.

The difficulties of starting are increased somewhat when using alcohol, due to the greater starting effort necessary for cranking the engine, and also because air at ordinary temperatures does not vaporize the alcohol sufficiently to make a good combustible mixture. Satisfactory starting was accomplished by a redesign of the starting-crank, coupled with the use of a mixture of four parts of alcohol to one of gasoline.

Conditions Necessary for Proper Use of Alcohol

In our case 110-lb. compression proved most satisfactory. Very liberal provision for heating the fuel charge must be made. The use of the entire exhaust heat will be found necessary. The temperature of the ingoing charge of fuel, for good carburetion and economical operation, should not be less than 100 deg. fahr. Careful consideration should be given to the design of the intake-manifold to obtain uniform distribution. At high compressions this is essential, especially when using alcohol. Gas velocity is important. The intake-manifold gas velocity, at full load, should not be less than 9500 ft. per min. on the average.

These are a few fundamental figures to work from. In our opinion alcohol is an ideal fuel, vaporizing at practically a constant temperature. This is a decided advantage; once the engine is properly warmed up, the operation is all that can be desired. Practically no carbon residue is created when using alcohol. The condition of the valves and valve-seats after long periods of heavy runs was surprisingly good.

We are thankful that it was necessary for us to do this experimental and development work with alcohol. In our opinion the use of alcohol as a fuel is bound to come eventually in the United States. We believe that the entire automotive industry should get behind this idea and bring it to pass as quickly as possible, so as to provide another source of fuel supply and to bring down the operating costs of all equipment depending now on hydrocarbon fuels. There are in the United States yearly millions of tons of unused vegetable matter from which alcohol could be profitably manufactured. If the automotive industry will demand the manufacture of alcohol for fuel purposes, it will head the list of automotive fuels eventually.

AMERICA'S FIRST AIRWAY

THE establishment of well-organized air routes throughout the country, especially in America, is as essential to a well-balanced system of national defense and as the development work on the aircraft itself. The limitless and boundless ocean of the air, must be explored, and charted just as unknown lands and oceans, so that navigators can with ease make their way without any loss of time or encountering any danger across vast expanses of territory in peace or war. The installation of an airway entails the location of landing fields with all accessories, including radio direction finding, radio communication, aids to night navigation, housing and maintenance of equipment. It is undoubtedly true that with properly established airways of this kind, cross-country flying by night or day, in good weather or bad, will be safer than automobile road touring and, with the development and perfection of the machine itself, will in time surpass in speed, comfort and safety the modern comforts of transportation. These air routes will provide a network whereon the units of the National Guard and the organized Reserve can be placed. However, these highways of the air will not be usurped by the Air Service but they will be open, under legislative restrictions, to all commercial operators who will receive all the benefits and conveniences of such an organization, therefore commercial aeronautic interests will be fostered. One vital point of value in the creation of national airways is the convincing of the public that aviation control is a matter of Federal rather than State legislation.

The Model Airway which will shortly be established between Washington and Dayton, Ohio, will be the first unit in a comprehensive system of airways throughout the United States which will be started under a policy formulated by the Army Air Service and which will be guided in its organization by the experience gained from the establishment and operation of the Model Airway. The Model Airway as chosen is extremely well suited to the purpose of serving as a basic guide in this expansion program. Almost all of the natural problems attendant to successful air navigation are met on this airway, which is one that will always be needed. In the course of this route appear mountains to be passed over, varying climatic conditions, and terrain of almost every type and character.

The Army Air Service is unable of course to purchase any land or make any expenditures in connection with the creation of this airway but can provide such equipment as is available for getting the route established. The small expense attached to the installation of this route naturally should fall on those who will receive the direct benefits of its existence and operation such as the communities, organizations and individuals along the route. The Army Air Service will gladly supply all the advice, specifications and information relative to the creation of the airway. This information would pertain to such things as landing fields, radio hangars, etc., and even might include the sending of qualified officers to superintend or consult. Certain terminals on the airway will have gasoline, oil and spare parts for both Government and civilian aircraft. Charts will be made of the entire route at the request of the Army Air Service and a photographic map will also be prepared. Oblique aerial photographs of every city, landmark and landing field will be taken and arranged in such form as to provide a guide to the route. Copies of these books can be signed for at one end of the route and turned in at the end of the journey. Flyers along the route will be in constant radio communication with each other and with the various ground stations and in case of fog or clouds will be directed along the route by radio. Should a group of commercial ships that are unequipped for wireless desire to negotiate the route, then an airplane so equipped can be dispatched with them along the route and they can "follow the leader" in perfect safety. A system has been devised for marking the landing fields along the route for purposes of identification and will serve as an aid to navigation.—Air Service News Letter.

MOTOR VEHICLES PER CAPITA

FIGURES recently compiled by the American Automobile Association indicate that in the year ended Dec. 31, 1920, 8,234,490 passenger cars, 945,826 commercial vehicles and 271,230 motorcycles were registered. The gain in registration over 1919 amounted to 2,114,870, which is the greatest increase ever recorded in a single year. According to these statistics there is on the average one motor vehicle for approximately every 11 persons in the United States.

The total receipts from registrations in the year 1920 amounted to $99,141,097 or more than one-fifth of the total annual expenditure for roads and bridges in the United States. Compared with 1919 these receipts increased $34,443,842 or 53 per cent, which is the largest increase ever recorded in one year.

The Care and Maintenance of Motor Trucks

By N. J. Smith[1]

Chicago Truck and Tractor Meeting Paper

THE object of this paper is to point out some of the difficulties which present themselves in motor-truck maintenance, and to suggest, if possible, the lines along which improvement seems most needed, in order that these difficulties may be reduced to a practical minimum. Sometimes the buyer and user of a motor truck experiences disappointments due to a lack of coordination between the engineering department and sales department of the truck company. The term "service" is often misunderstood by the purchaser of the truck and misrepresented by the salesman. With the exception of a few minor adjustments, service is sold and not given, but the buyer sometimes understands from the salesman that he is to receive free service, and so a misunderstanding arises. Again, salesmen sometimes make claims and promises which are unauthorized by the factory or the engineering department, and upon which they are not prepared to make good. A dissatisfied customer is likely to be the result, because he feels that things have been misrepresented to him.

All such trouble could be avoided by a better working agreement between the factory and the sales force. Salesmen should have accurate information on the service policy of their company, and on all guarantees which they are authorized to make. Furthermore, when the prospective buyer asks questions in regard to the engineering or mechanical details, the salesman, if unequipped with accurate information, should not draw upon his imagination, as is sometimes the case, but should get the desired information from the proper source. In this way a complete understanding between the seller and the buyer would exist from the start, and the latter would know exactly what the truck is supposed to do when he places it in service. It seems to me that this question of co-operation between the engineers and the sales department is an extremely important point in the psychology of selling and buying a motor truck. The buyer must understand exactly what he is buying, what it will do and the circumstances under which it will operate properly. The salesman is the man from whom he must get most of this information. The engineer is particularly interested in turning out a truck that will run a long time in a satisfactory manner. No matter how well his truck may be built, it will not stand abuse. Consequently, he is vitally interested in having the salesman educate the customer, and in making sure that the salesman, in his eagerness to make a sale, is not losing sight of the necessity of the truck finding a good home.

The country is full of trucks running at excessive speeds in spite of a 100-per cent overload; perhaps doing work that could be performed more economically in some other way. They are left in the garage over-night and take up their work again next day without having received the proper attention to make them fit for the street. It is a hopeless task for the poor truck, and extremely difficult for the best. The result is very likely to be an early journey to the junk-heap, and a dissatisfied customer, and the cause all to often is the salesman.

While a motor truck is in the repair-shop it is a source of double expense; indirect expense due to the overhead, because it is idle and earning nothing to meet interest charges, and because of the loss of use while it is being repaired. This latter may be a cause of serious loss and inconvenience, the exact amount depending upon circumstances and being very difficult to estimate; second, direct expense for labor and repair materials. That these two items may be kept as low as possible, the truck builder must keep two things clearly in mind. First, the design of each individual part, and the material and workmanship which go into it must be the best that can be procured, in order that the breakdowns may be as infrequent as possible. Second, the assembly and coordination of the various parts into the complete truck must be accomplished with the accessibility of all these parts constantly in mind. The first of these requirements will reduce the direct expense for repair labor and materials, and the second will make possible a substantial reduction in the time required for repairs and renewals, which will mean a saving in labor and also in overhead expense. It must be kept clearly in mind that a truck in the repair-shop is an idle truck, and anything which will shorten the period of idleness promotes economy, entirely aside from the more evident saving in the mechanics' time in making repairs.

Needed Improvements in Design

I shall now endeavor to point out specifically a few points where our experience in the operation of a large fleet of motor trucks indicates that improvements are needed. Based entirely on my experience in motor-truck maintenance, I do not hesitate to say that ignition is one of the weak points in the motor truck to-day. In fact, when a service call comes in from one of our trucks on the road, we invariably send out a new magneto because we find very many times that there is where the trouble lies. This does not apply, of course, in cases where the drivers know where the trouble is, but only in cases of engine trouble, the exact nature of which the driver does not know. In other words, engine troubles are due to faulty ignition more often than to any other cause. With the possible exception of poor or inadequate lubrication there is probably no condition which contributes more to rapid engine depreciation than faulty ignition. Carbon accumulation, dilution of crankcase oil, fouled valves and spark-plugs and general irregular and faulty performance are all chargeable to poor ignition. All these conditions increase enormously the service labor and expense required to keep the truck in operation.

I believe that designers and builders of motor trucks should give serious attention to the improvement of the magneto. In the present state of the art it is possible, I think, to build a better magneto than is being used at

[1] Consumers Co., Chicago.

present on motor trucks; one that will operate for a long time with practically no attention save lubrication. It is probable, of course, that such a magneto would be more expensive than the present equipment, but intelligent users of motor trucks would be glad to pay the increased cost if assured of a better device. Operating savings, due to the elimination of the many ills which follow poor ignition, will repay them many times over for the increased cost of the better magneto. The breaker-box and platinum points give a great deal of trouble. Would it not be possible to make a dirtproof breaker-box?

There are a number of fairly good carbureters on the market, and others not so good. In my opinion, the gasoline engine has by no means reached the end of its development, particularly along the line of efficient use of fuel, which is largely a carburetion problem. When 25 to 40 per cent of all the heat in the fuel is contained in the exhaust gases, in the form of unburned or partly burned gasoline, it would appear that there is room for improvement. I believe that this improvement can be brought about to a considerable extent at least through a better control, over a wider range, of the proportions and the temperature of the fuel mixture. This control must be automatically governed by the load demands on the engine in the interest of both power and economy.

While we await the advent of more efficient carburetion equipment, the present carbureter should receive a little attention from the designer. It should be made as nearly foolproof as possible; adjustments must be few and simple, approaching automatic operation. More attention must be given to the effect of vibration on the operation of a carbureter. Leaky floats and valves often caused by vibration are wasteful of fuel and constitute a fire hazard. Furthermore, needle-valves and seats poorly designed or imperfectly made are a frequent cause of annoyance and delays.

I believe it is the general consensus of opinion among motor-truck builders that a reliable and efficient governor is highly desirable. Because of the rapid depreciation caused by high speed, the life of engine and truck depends to a considerable extent on the efficiency of the governor. Our experience with governors is that very few of them function properly. They require almost constant attention to keep them in working order and if they are neglected the engine will soon be running wild. The average driver likes speed and cares little about truck depreciation. A governor must be simple in design and of the very best construction as to materials and workmanship. A better means than is now available for sealing the governor should be devised. It seems to me that a lock should be used, having a key which the owner or the garage superintendent can retain in his possession. This will tend to assure proper operating speeds, which are an excellent insurance against engine troubles.

Lubrication of the moving parts on the chassis is usually taken care of by the installation of grease-cups. In principle at least such a provision should be ample, but in practice the user of the truck frequently finds that the results are not satisfactory. If the filling and turning down of the cups is made a part of the driver's duties, it is almost certain that it will be neglected. I believe that fully 75 per cent of the trucks on the street are insufficiently or improperly lubricated, largely due to the fact that the driver neglects this important duty. We find from our experience that it is much better to have the greasing of the trucks done in our garage, at regular intervals, by service men assigned to this particular duty. In this way the work is more systematically done and results are much more satisfactory. But even with this system a grease-cup will occasionally be neglected or overlooked, especially if it is located in an inaccessible position.

The design of grease-cups leaves much to be desired from the point of view of the maintenance man. They are generally cheap stampings with coarse threads. The threads are very often crossed when endeavoring to fill and replace the cups in some inaccessible place, and as a result the cup is ruined. Constant vibration frequently jars a grease-cup loose, and once it is lost it is seldom replaced. It seems to me that if a grease-cup could be developed along the lines of the self-feeding compression type, lubrication would be much more efficient and maintenance expense materially reduced. If such a cup were developed, it would probably be necessary to use greater care in selecting a lubricant properly adapted to the weather and temperature conditions under which the truck operates. But this can be taken care of by the garage or service department, and need constitute no valid objection to a substantially automatic grease-cup, if one can be designed by the builders' engineers.

My experience indicates that attention should be given to the equipping of truck wheels with non-skid devices for operating in mud, snow, or ice. Many builders make no provision for any such device; others have made attempts, but I know of no successful solution of this important point. I have sent out trucks in the morning equipped with six chains on each rear wheel; at night they have come back with only one chain left. These chains are very hard on tires and springs, and impose serious strains on worm-gear drive-axles. The builder who can solve this important problem will make a valuable contribution to the motor-truck industry.

In connection with the above, I believe that some serious thought should be given to the question of cushion whee's. I am not prepared to make suggestions on this point, but believe that a good cushion wheel is much to be desired.

A motor truck is a compact, highly specialized piece of machinery, and when the final assembly is complete it is almost inevitable that some of the parts should be extremely difficult to get at. To save time in making repairs and renewals, all parts which, from their nature are most likely to need attention, must be readily accessible. Among these parts, the engine, transmission, magneto, water-pump and grease-cups may be mentioned.

The engine should be installed in such a way that it can be readily taken down for repairs. We have trucks from which the entire engine can be removed by two men in 1½ hr., and we have others which would require three times as much labor for the same job. Some engines are built so that the bottom half of the crank-case is readily removable, providing access to crankshaft and main and connecting-rod bearings with a minimum of labor. This is important, because as every maintenance man knows, the labor of taking down an engine and reassembling it after the repairs are made, is often the largest part of the job.

The above considerations in regard to engines apply to transmissions also. From our experience it seems that very few builders using a transmission amidships make any provision for filling or inspecting it except through the top. If any other than a dumping body is placed on the chassis the transmission is inaccessible, and if something goes wrong the body must be removed to get at it.

As pointed out earlier in this paper the magneto is a frequent source of trouble and must be repaired or re-

placed. Consequently, it must be readily accessible, and also the shaft or other means of driving it. The removal of the magneto necessitates disconnecting it from the shaft, a difficult job in an inaccessible place.

Frequently the water-pump is placed in such a position that replacing becomes extremely difficult. Both the pump and the magneto may be driven from the same shaft, located where it is readily accessible from end to end. Some designs place this shaft in a transverse position in front of the engine, which in general provides greater accessibility than when it is placed in a fore-and-aft position by the side of the engine.

A grease-cup located where it cannot be reached readily is little better than no cup at all. I believe that until automatic grease-cups are devised, motor-truck builders should do everything in their power to design their machines so that the grease-cups are easy to reach, and replacing, filling and screwing down can be done with a minimum of time and labor.

Maintenance Practice

I have been asked to speak also of the care and maintenance of motor trucks. This is rather a wide subject, and I feel that I shall be telling some of you things that you already know. The Consumers Co. operates 159 motor trucks, which cover the entire city of Chicago and the outlying districts, and each day are delivering coal, ice and other supplies. Keeping these trucks on the road and cutting down expenses or making the maximum haul at a minimum cost is my job. Naturally, in the pursuance of this work, we are always on the lookout for every possible place at which we can effect a saving. It has been our experience, as I will tell you, that in no place is the expenditure of money more justified, or does it bring greater return, than in keeping our fleet *away* from repairs. I mean by this, treating all our equipment with such inspection and nightly adjustment that it is kept constantly up to a high level of mechanical efficiency. This means, to be exact, that as little time as possible is spent in the garage, or out of active work. I will show you how we have formed our organization to bring this about. I shall not go into details over the truck on the road, the routing, or the means by which we keep in touch with our equipment while it is moving. The modern loading and unloading devices have already shown their efficiency, so I shall not speak about them other than to mention that in our larger yards we load by overhead locomotive cranes that are capable of loading from 2 to 10 tons in 2 min. The time taken for our trucks to get into the yard, get their load and out again is usually under 5 min. As some of our trucks make us as much as $1.20 per ton, you can readily see our anxiety to keep them moving. A truck standing still earns no money.

What I do want to talk about is our garage and shop equipment. Here is the power behind the throne. This is where the trucks are kept fit. It is here that the very backbone of our system is kept nourished. Without proper maintenance, a truck cannot bring in the profit that it should. "All the trucks on the road all the time" is our motto; we try to live up to it. Here is where we differ from the modern acceptance of repairs, "the chief part of maintenance," as some put it. He is a poor doctor who will let his patient get into such a condition that the only thing which will save him is an operation. It is just as poor policy to let the first attention you give a truck ailment be a repair. Then the damage is already done and your truck will suffer forever afterward as a result; no matter what reparation you make to the injured part. It is the ounce of prevention that pays. Let me emphasize this statement strongly. Nearly all our energies are devoted to keeping the trucks from ever getting into such shape that they will need overhauling. Does it pay? It does. We have some trucks that have gone over 70,000 miles and are, as near as we can tell, in as good a condition as the day we bought them from their builder. There are some that are more than 4 years old, and show no evidence of wear. Does this speak for the wisdom of our system?

Trucks on the road are constantly under a stress and strain. This tends to make their lives shorter than any other kind of transportation machinery. It is this depreciation that we fight. In prolonging a truck's life we reduce our cost per mile of haul with that truck. We have not effected these results without expense. Some of the items of cost have been fairly high and were some time in proving their value, but we are reaping the crop now. I do not think that you will consider it boasting if I say that I think we are delivering coal and ice cheaper than anyone else in the city of Chicago.

Our garages have been the subject of great care and thought. Much of our work is done at night. We have built the garages with an eye to two results; fast work and good work. Here is where these trucks are washed and inspected each night, and I might say that each truck gets this each night. Clean floors and walls of fireproof construction add to the appearance and reduce our fire risks. All inflammable gases are taken out through the wall construction. There are plenty of windows for pure air and there are few shadows. Also there are no columns to get in the way of truck or man. The floors are stripped for action. You must remember that we have over 159 trucks and each one of these has to receive an inspection, a wash and a general cleaning every night in the year. This inspection is nothing in the way of a casual "once over," but a careful looking over of each truck as it is checked in at night. By keeping our floors clean and well drained, our men are able to wash a much larger number of trucks than they would in the same time on a floor with bad drainage. Our washing and draining systems are arranged so that it is possible, in case of necessity, to wash any truck wherever it stands in the building. Our rule, however, is to have all trucks sent to the special washing floor. This floor is free from shadows as it can be. This gives the man ability to see his work so that he can get it done faster and better.

Our plumbing system is arranged for both hot and cold water. Steam boilers keep the soap and water as well as the suds at the correct temperature at all times during the washing period. This was a large expense in plumbing, but a huge saving in labor cost is the result. To avoid sewer stoppage we have large catch-basins. These are cleaned every 7 days. As tons of dust are washed out of the trucks, care is exercised to keep this from getting into these basins. The floors are cleaned with large scrapers built so that one man can handle them. This done, the floors are washed, and this is done every day. You will probably think that I am spending a long time getting my subject cleaned, but it is necessary, for now we come to the inspection. Much of the cleaning is done to bare the surface of all the truck and its mechanism so that the inspector can see if there is anything wrong. A hundredth of an inch of coal dust can cover up a multitude of troubles.

Our inspectors have good eyesight. If through laziness they become blind, they also fall heir to another position. The mechanics go over the truck every night,

tightening brake-bands, straightening mud-guards and checking up on all the little things that may go wrong with the truck, and catching these flaws before they develop into serious troubles. Back of them all are the inspector and his assistant. The driver's trouble card has already eliminated any truck that has shown any minor or major trouble, and it is these trucks *apparently in good condition* that the inspector searches through to find the trouble that is brewing. That is where the ounce of prevention comes in. This inspector and his assistants cover all the trucks once every month. Not one single part being overlooked. This man has a printed form covering all parts of the truck. The inspector covers the engine in detail; the spark-plugs are adjusted and the compression of each cylinder is taken. In this way we are better able to tell when the cylinder needs regrinding. The transmission is gone over to determine the condition of the gears and if necessary filled with grease to the proper level; the clutch is carefully tested; universal-joints are Alemite equipped which saves much time in filling; and we never find one dry. The wheels are taken off and bearing cups and cones are cleaned and gone over carefully for worn or defective parts. Before assembling a fresh supply of grease is put into wheels, and the bearings very carefully adjusted. Since installing this system of looking after the bearings our wheel bearing trouble on the street has disappeared. All grease-cups are checked up to see if the men doing this work are doing it efficiently. The cooling system is closely checked. Rear ends and tires are checked up and their condition reported. The hoist and body are also covered. It may interest you to know that it costs as much to maintain one of these dump bodies with hoist per year as it does to maintain all the rest of the truck. This inspector's card shows also whether the engine is being kept clean, if the truck is being washed; everything must be in perfect shape or reported for repairs, so when this card is turned into the office it shows the mechanical condition and appearance of the truck. If you had a passenger car would you like it to get this treatment every month? Would it pay you?

Now comes the slippery subject of greasing and oiling. Just as we have one man to wash from 12 to 15 trucks, we have one man whose sole aim in life is the greasing every night of from 15 to 18 trucks. That is his job and on the proper performance of his job rests to a great extent the proper performance of our trucks. I will give you an example. How many operators pay any attention to springs? Practically none that I can think of. With us this is an important item. Every spring is washed down with waste oil. As a consequence we have practically no spring trouble; and this in face of the fact that the majority of our equipment is of 7½-ton size carrying a 33-per cent overload day-in and day-out. When we take a truck down for overhauling, we invariably find the spring leaves well separated, with no rust present and lots of grease worked through. Under similar conditions, on most trucks you will find spring leaves frozen together into a solid mass of rust and metal. Such a spring lacks resiliency. This means a saving that is hidden at first thought, the saving on tires.

Handling Repairs

Sometimes, strange as it may seem, even our trucks will get out of order. In other words, they will not run. If this happens on the road, we send a service car to make the truck run or tow it in. We do not allow our trucks to "limp" in.

Minor repairs are made by mechanics capable of doing almost any kind of a job with a reasonable amount of speed and accuracy. This is done at the garage during the night. Jobs that consume several hours or more are listed for the shop. This shop is always in the hands of an experienced man. In laying out the building special attention was paid to ideal working conditions and making the men happy; good light and ventilation mean good work.

In the selection of tools and equipment, a study is made of each individual operation to find the best means of handling it. If after a careful analysis is made, it is found that tools or machinery will make a saving, these are installed. Without great care in the selection of machinery and tools it is an easy matter to fill up valuable space with machinery that will not pay the interest on the investment. Our shop equipment consists of shaping and milling machines, air hammers, drilling machines, drop hammers, special reamers for all bearings, wood-working machines and machines for painting. As we have been able to standardize our automobile equipment to a great extent, we are able to save in shop equipment as well as in our stock of parts. This is an example of standardization. Our machinery equipment is laid out on the floor of our shop so that repairs can be routed through in the most efficient manner, thus saving the time of rehandling and doubling back to the same men.

From our stock records we are able to know just what parts we are likely to use in our garages during the night. Having this knowledge eliminates carrying all unnecessary parts, thus saving a large sum of money and time in keeping the record of these parts. The main stock-room is connected with our shop and carries everything that goes into the truck. Our garage stockrooms draw on this one for all parts. The shop has on hand at all times an extra engine ready to go into a truck in case one comes in with trouble that would necessitate taking the engine out. The extra engine is put into the truck while the one taken out is repaired and put into stock prepared for a similar case. This liberates an investment of some $8,000 to keep on with its work of earning money for us. We have extra electric motors and batteries for the electric trucks, extra wheels for both gasoline and electric trucks and complete steering posts; in fact any unit that our experience has taught us will save time and keep our trucks moving at all times. Our stockroom is arranged for keeping a perpetual inventory. There is no kind of job on a truck that cannot be handled in this shop.

All our men are most carefully selected. We treat them well and they know it. There is always a waiting list of applicants; by having a quantity to pick from we get a good type of man. There are factors in human nature that work against efficient organization and there are those that work strongly for it. Pride and contentment are our aids; and these we try to build up in our own men.

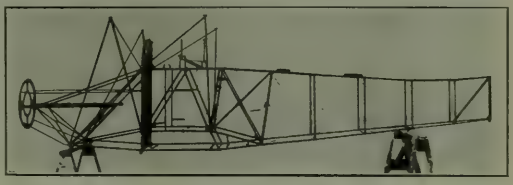
Perhaps what I have said today has not been efficiently specific. It may be that I have attempted to cover too much ground. I hope not. It is quite possible that some of you will think that we have built up too big an overhead for our equipment. I can only assure you that I have given you the honest result of our experiments and experience. It is more economical to spend money in the prevention of trouble than it is to let the opportunities for saving slide by, gamble against the law of averages, and then, in the end, pay the same amount of money and more to repair defects.

Recent Progress in Military Aviation

By Major H. S. Martin,[1] U. S. A.

Annual Meeting Address *Illustrated with* Photographs

With the time available it is possible to give only a brief outline of my subject, and much of importance will be neglected. I will endeavor to give in a few words an idea of recent progress by the Engineering Division with its diversified problem of the development of all heavier-than-air equipment for the Army Air Service. Briefly stated this problem includes the development of the 15 types of airplanes, embracing those for pursuit, attack, observation, bombing and training, at present believed necessary to fill Air Service requirements. When we consider that a military airplane carries from 1000 to 20,000 lb. of crew with oxygen, parachutes, other conveniences or necessities, fuel and oil, machine-guns, cannon, ammunition, sights and instruments of various kinds, bombs, photographic and radio equipment, a total distance of 300 to 1000 miles or more, and at a speed of from 100 to 180 or 190 m.p.h., and that the engine, all armament and equipment must operate or be operated satisfactorily at air temperatures varying from 100 deg. above to 50 deg. below zero, fahr., and in all weather conditions, the diversity of the problems encountered will be appreciated.

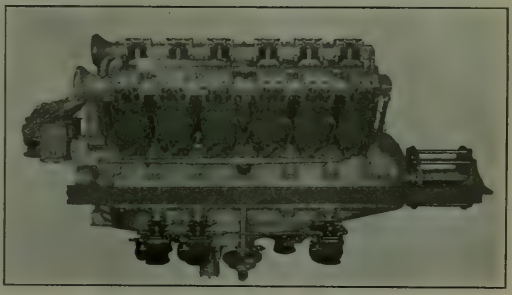


The Steel-Tubing Framework for the Fuselage of a Night-Pursuit Airplane

It is usually most convenient in a discussion to consider the complete airplane under the heading of the airplane proper, the powerplant, the armament and the equipment. The airplane proper is perhaps the least of our troubles. We are able to build airplanes strong enough, and thanks largely to the engines available we are rarely obliged to discard an experimental airplane because of poor performance. This, of course, does not mean that performances cannot be considerably improved. However, the installation of all that goes into an airplane is rarely accomplished to our complete satisfaction. It is a very difficult job and remains to be done in making satisfactory installations of engine, armament and equipment. The Fokker D VII with the Packard engine is an engine installation that provides sufficient strength and rigidity, and at the same time the engine is accessible, which means much to those responsible for keeping airplanes in commission. It is a neat installation that is not compatible with simplicity. The Verville Packard Racer shows a leaning toward the other extreme. This is not a strictly fair comparison since this airplane was not originally designed for the engine.

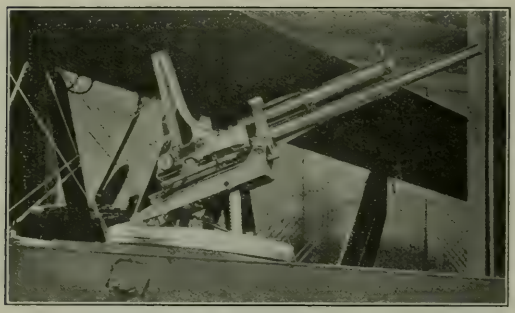
The Verville Messenger and the Martin Night-Bombing Airplanes

Going to one or two of the types at present considered to fill Air Service requirements, we have the Thomas Morse MB-3, a single-seater pursuit airplane with the 300-hp. Wright engine. Some of these airplanes will soon be in service on the Border. The G. L. Martin Co. MB-2 is a short-distance night-bombing airplane with two



The Type W 700-Hp. Engine Which Has Been Developed by the Engineering Division of the Air Service

[1] Engineering division, Air Service, McCook Field, Ohio.



THE 37-MM. CANNON MOUNTED IN AN AIRPLANE

Liberty 12-cylinder engines. This airplane is a development of the Martin bombing airplane originally delivered to the Air Service in 1918. The small airplane shown in front of the Martin bombing airplane is the Verville Messenger. This airplane was built by the Lawrence Sperry Aircraft Co. in accordance with a design furnished by the Engineering Division. The original idea was an airplane for messenger work, but it is possible that it may be of use for training.

For night pursuit we have a recent acquisition in the Curtiss Co.'s NP-1 airplane with the Liberty six-cylinder engine. This airplane is still experimental, having just completed its static test. The construction of the fuselage is of steel tubing.

Perhaps the best method of laying out a new design is that requiring a mockup which is a model true to size of an airplane with the engine and all armament and equipment installed. In this way the clearances, location of armament and equipment and engine installation can be studied and corrected far better than by drawings.

DEVELOPMENT OF ENGINES

Going to the question of engine development, our first task has been to develop existing engines, especially the Liberty 12-cylinder type and Wright 180 and 300-hp. units. The Liberty engine has been fitted with inverted carbureters which have improved the operation and are at the same time much more accessible for adjustment. The altitude control has been improved and made effective at higher altitudes. The Wright 300-hp. engine has been fitted with inclined magneto brackets, making a simpler engine-bed possible and eliminating the necessity for right and left-hand magnetos.

A LARGE CANVAS HANGAR CAPABLE OF HOUSING THREE MARTIN BOMBING AIRPLANES

Very many engine tests have been conducted with a view to improving engine performance. With anti-knock fuel and high-compression pistons consumptions lower than 0.45 lb. per b.hp.-hr., in one case 0.42 lb., have been observed. This places aviation engines on a footing with the best Diesel engines as regards fuel consumption per delivered horsepower-hour. A large number of single-cylinder tests have been made of air and water-cooled engines under construction or being considered for production. One test of a 5½ x 6½-in. water-cooled cylinder with four spark-plugs showing an increase in power, but the gain in using more than two plugs is probably not worth the added complication. The General Electric supercharger for the Liberty engine, with the variable-pitch propeller, is being given flight tests. Steps have been taken to develop a supercharger for the Wright 300-hp. engine. We also propose letting a contract for a gear-driven supercharger.

Our work in the development of new types has been largely concentrated on large water-cooled engines and air-cooled radial engines of from 60 to 350 hp. The 700-hp. Model W engine designed by the Engineering Division, which is now starting its first run, is shown. A reduction gear for the engine has been designed and will be constructed.

The preliminary design of a 1000-hp. 18-cylinder engine is completed and work is progressing on the complete design. The Packard series, an eight-cylinder for training, a small 12 for pursuit airplanes and a large 12 for bombardment types, have completed their tests. The large 12 is the engine installed in the Verville Packard Racer. Additional small orders have been placed for these engines with modifications. It is proposed to increase somewhat the size and horsepower of the small 12-cylinder unit. The Wright cannon engine is being modified as a result of its tests and we hope to have soon a satisfactory engine for the 37-mm. cannon.

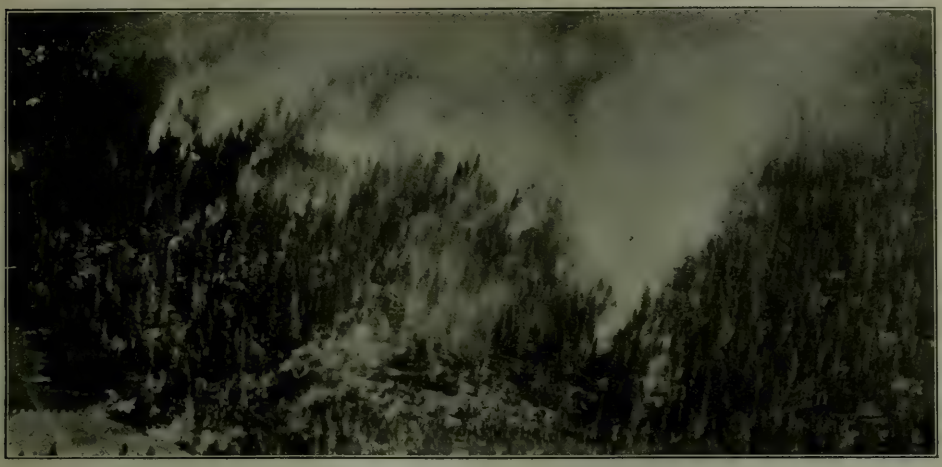
The radial air-cooled types are being covered by the Lawrence 140 to 160-hp. for training airplanes, and the 350-hp. Weinberg and the Wright engines for service types. The Wright engine has started running, the Weinberg is being prepared for its preliminary tests and we hope to have the Lawrence soon.

For a radial water-cooled engine we have under consideration one of the barrel type known as the Almen engine. This engine will permit a cannon to be fired through the crankshaft, and in addition an engine of this type of 350-hp. would have a diameter of about 18-in. and a length of about 36-in. This feature of compactness is of course a great advantage. While the general idea is not new, it is believed the present model offers a chance of success, and its advantages justify the expenditure of some time and money.

PROBLEMS OF ARMAMENT DEVELOPMENT

Passing to armament development, the main problems are to mount the fixed and flexible machine-guns and cannon of varying calibres so as to provide for the satisfactory feeding of the ammunition and the ejection of the empty shells, to provide for the synchronization of the fixed guns and to provide for carrying bombs. We endeavor to provide for interchangeability of the various types of machine-gun. It should be explained that the Ordnance Department of the Army manufactures the machine-guns, cannon and bombs used by the Air Service.

The location of fixed guns has been confined to rather



PHOTOGRAPH OF A FOREST FIRE TAKEN FROM ONE OF THE AIRPLANES OF THE FOREST PATROL

narrow limits because they are synchronized by a device driven by the engine, usually by mechanical means. With the development of the electrical synchronizer the problem will be greatly simplified, since wires are more easily located than tubes, rods or cables. In mounting flexible guns three of the requisites are field of fire, ease in operation and rapidity of fire. The field of fire is somewhat dependent on the design of the airplane, but a new mount has been developed which increases the field of fire and is reasonably easy to operate. To assist the observer or gunner in handling the guns, a wind compensator for the flexible mount has been designed and constructed. The force required to move two guns as well as oneself against a wind blast of from 125 to 150 m.p.h. would ordinarily

TYPICAL COUNTRY COVERED BY THE AIRPLANE FOREST PATROL

be underestimated, and the compensator is designed to assist the operator by means of springs.

For securing volume of fire, a mount to carry four Lewis guns has been constructed. To take advantage of the rapidity of fire of the Browning it has been mounted flexibly. This has necessitated designing a reel for the ammunition similar in purpose to the Lewis gun magazine. The 37-mm. cannon has been mounted in almost every conceivable position in the airplane where it would be of any use. The 2.95 mountain gun has been mounted and fired from the Martin bombing machine.

Equipment Development

Equipment development has been confined largely to crash and leakproof tanks, parachutes, hangars, take-off mats and cameras. Work has been done on navigation instruments and the use of radio for navigation. One instrument deserving mention is the universal gasoline gage which will go in any tank from 10 to 50-in. in diameter, and also permits some choice in the location of the dial.

Crashproof is a term applied to tanks designed to prevent gasoline spilling all over the engine, with fire resulting, in a crash which often splits the tank. The tanks are of the usual construction except that they are covered with a thin bag of live rubber. Experiments show that this is an advantage.

The development of leakproof tanks is being continued but the advances in the armament of airplanes with heavier calibres and more destructive ammunition will apparently require a new and different solution before long.

Satisfactory parachutes of the back, seat and lap type have been developed, and some are in use. The back type will probably be used for training, while the seat and lap types will be used for service. The latter types are somewhat smaller and better suited for service because of this, and also because they interfere less with the operations of the pilot, observers and others. In an attempt to get the parachute entirely out of the airplane, and yet avoid the disadvantages of the type attached to the airplane, we recently experimented with what is termed the detachable parachute fuselage. The parachute is carried in the rear of the fuselage and in case of accident the pilot pulls a lever disconnecting himself and the rear of the fuselage.

The technical development of radio is under the direction of the Signal Corps of the Army, the Air Service making service tests only. One phase of these tests is an automobile equipped with radio with which it is possible to keep in communication with an airplane, while the automobile is running along the road.

The development of hangars is a difficult problem. The effort to make them easy to erect, take down and transport, and yet withstand all weather conditions results in something of a compromise. One recently constructed by the Henrix Leubert Co. which is perhaps the largest canvas hangar yet constructed and will house three Martin bombing machines is shown.

To enable airplanes to take-off in muddy fields we are developing so-called take-off mats. Although it might appear a relatively simple matter, it is very difficult to provide 300 or 400 ft. of a satisfactory width to stand up under rough treatment, and yet not require too much in the way of trucks to transport it. At present there are two types, one a rope net with canvas, the other a canvas mat with hickory slats.

The Forest Patrol furnishes excellent opportunities for service tests of aviation material, and at the same time is doing a great amount of good. Under the direction of Col. H. H. Arnold, this patrol has been operating over the States of California and Oregon. From about the middle of May until the end of September the six stations made over 1200 patrols for a duration of 4000 hr., and over 1600 fires were located and reported. In this flying time there were 41 forced landings, or one to about every 100 hr. of flying, or one to about 30 flights. It is interesting to note that the station flying the greatest time had no forced landings. Since the equipment was substantially the same this shows the possibilities in properly taking care of equipment, although other conditions enter. Notwithstanding the character of the territory flown over, as shown by the illustrations, there was only one fatal accident.

FEDERAL HIGHWAY COMMISSION URGED

AFTER a careful survey of the highway question I feel that the best way to focus the attention of the public on this great problem, is through the creation of a Federal Highway Commission, which should take over the work of the present Bureau of Public Roads, and I say that without the slightest criticism of the men in charge now who are doing all that they can under the limitations of the present law. If a commission of five men could be appointed by the president with the advice and consent of the Senate, several results would be obtained at one stroke. In the first place, highways would be given their proper place as the most important single domestic phase of the Government work. Not only would the recognition be a proper one, but it would serve to stimulate the interest of the students in college, to whom we must look for our future corps of trained men to handle the vast expenditures now available and to be made in the future. We would have a body of men in charge of the work whose duty it would be to look at the question from a national rather than a sectional viewpoint, although their selection from varying geographical centers and cooperation with State highway departments would insure the latter against any neglect of local conditions. Instead of the possibility of a change in policy such as is always possible where the administration changes each four years, we would have a continuing policy, as these men would be appointed in rotating years, thus keeping at the head men constantly informed as to the work at hand.

Any men selected should be big, mentally. They should be selected because of their knowledge of the subject rather than from a political standpoint, and to present a rounded viewpoint, they should include engineering, industrial and agricultural minds, although not necessarily men engaged in those occupations at the moment. These men could then sit down and with State officials could shape a national policy which would take into account national as well as State needs. Their report to Congress would naturally give us the basis for the soundest possible national policy and one that would insure the wisest expenditure of funds.

The actual construction work should always be undertaken by the State departments under Government supervision, where the State departments have the power and ability to do so. The present regional districts should be retained and every effort made to avoid duplication and overlapping since any upbuilding of national construction forces where State organizations are effective, would defeat the very purposes in mind. Present experience points to a concentration of national funds on a selected national system which should be built and maintained at Government expense.—Edward S. Jordan of the Highways Committee of the National Automobile Chamber of Commerce.

Investigations of Road Subgrades

By A. T. Goldbeck[1]

Annual Meeting Paper *Illustrated with* Charts and Drawing

ALTHOUGH road engineers have long realized the necessity for properly supporting the road surface, only in the past few years has there been a more general recognition of the value of a close study of the subgrades of roads. Let us review some of the conditions that have forced upon us the desirability of looking into the subgrade; then we shall have a better understanding of just what we mean when we speak of the "subgrade problem."

When traffic loads were comparatively light, little trouble, except in isolated cases, was experienced with the failure of the surface to support the load, but as motor trucks have become heavier and heavier numerous cases of road failures are reported from various sections of the country. In some cases these failures are so frequent and so general as to interfere seriously with the serviceability of the road and its entire reconstruction has had to be undertaken after only a few years of service.

Just what do we mean by a subgrade failure of a road and what are the conditions that bring it about? Our higher types of road such as are used for motor-truck traffic are not capable of much distortion without cracking or weakening of the road structure. If the strength of the road slab as supported by the underlying subgrade is insufficient to prevent undue distortion under the heavy concentrated wheel loads of trucks, failure of the surface results through the cracking of the slab, and if the subgrade is very soft little time is required for heavy traffic to break up the surface completely and churn it with the underlying mud. Pavements having little or no slab strength will likewise suffer from undue distortion and soon break up under traffic when the subgrade is soft. In many cases, although the incipient failure has produced cracks or serious distortion of the pavement, the final failure may not take place immediately, but the pavement is placed in such a condition as to involve high yearly maintenance expense. If the road surfaces are adequately supported to prevent undue distortion under heavy loads, we should have very few complete and rapid structural failures of roads; they would then fail only after long periods of service through gradual surface wear and disintegration.

The problem of the subgrade is evidently that of finding what causes certain kinds of subgrade material to be soft and of very low bearing value and, having discovered this, to determine what means must be employed to either remedy the condition of the subgrade or fit the design of the road surface to the subgrade. Let us go into the matter a little further and consider something of the mechanics of the problem. Then let us think about some of the various factors involved in producing an unstable condition in the subgrade. First, what happens

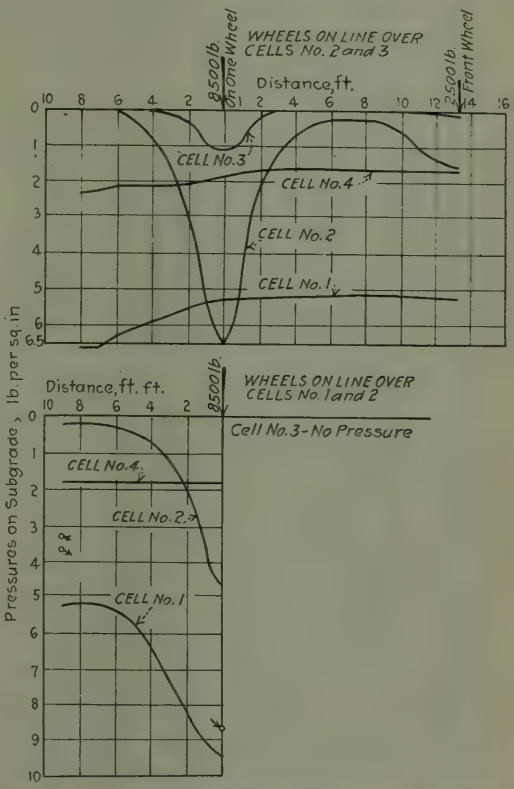

WHEELS ON LINE OVER CELLS No. 2 and 3
8500 lb. on One Wheel
2500 lb. Front Wheel
Distance, ft.
CELL No. 3
CELL No. 4
CELL No. 2
CELL No. 1
Pressures on Subgrade, lb. per sq. in.
WHEELS ON LINE OVER CELLS No. 1 and 2
Cell No. 3 - No Pressure
CELL No. 4
CELL No. 2
CELL No. 1

Fig. 1—Distribution of Pressures Obtained at Camp Humphreys with a Loaded Army Truck

to the subgrade when it is called upon to support the extremely heavy wheel concentrations of our large trucks? Let us assume that a high type of road having a wearing surface suitable for heavy traffic has been laid on a subgrade of uniform quality and that a heavy truck is at rest on the road surface. Under each wheel there is exceedingly heavy pressure and all of this pressure is necessarily transmitted to the underlying subgrade. The manner in which pressures are transmitted has been given practically no thought and is a subject very little understood by engineers. We have succeeded in gaining some information on this matter with the use of a special cell for measuring soil pressures, which depends in

[1] Engineer, Bureau of Public Roads, Washington.

principle upon the balancing of the soil pressure with air pressure within the cell and noting the air pressure required for this purpose. This device has been described in a previous paper.[2]

Tests at Camp Humphreys

Some few years ago a test was made on the Camp Humphreys concrete road in which the pressure distribution was determined under each wheel load. The intensity of pressure on the subgrade is shown in Fig. 1. It will be noticed that the highest intensity of pressure occurs directly under the wheel and that the pressure diminishes according to a curve and disappears about 6 ft. away from the wheel. It will be seen also that in this particular test the maximum intensity of pressure was 6½ lb. per sq. in. A complete description of this test was given in the Bureau of Public Roads publication, *Public Roads*, for April, 1919. The wheel-load producing this pressure was 8500 lb.

Similar tests were made with lighter wheel-loads and it was naturally found that the pressure on the subgrade was less with lighter loads. Very recently a similar test was conducted on the Camp Humphreys road in which a 5-ton truck was used, designed with four instead of two rear wheels, and the curve of pressures on the subgrade as given in Fig. 2 was obtained. This is very interesting because it shows immediately that heavy wheel concentrations produce heavy pressures on the subgrade, but that if the same gross load of the truck is supported on more wheels, thereby decreasing the individual wheel loads, the maximum intensity of pressure on the subgrade is likewise decreased; and, as will be pointed out later, this may mean the success or the failure of the road. Tractor trucks and the use of trailers would be of great advantage from this standpoint at least, since the large gross loads are carried by more wheels. Time will not permit of a detailed discussion of this test; the results are indicated here to point out to truck designers the fact that they can aid in saving our roads and incidentally make available more money for new construction by whole-hearted cooperation with the road engineer and a consideration of the possibility of designing the motor truck with the idea in view of ultimate economy of motor-truck transportation, and with the thought clearly in mind that ultimate economy involves the economy of road construction and maintenance as well as that of the operation of the motor truck. Other tests we have been making point so clearly to the desirability of close cooperation between the motor-truck designer and the road engineer that I have felt warranted in making a brief digression from my subject. I refer to a large series of tests that have been showing us some surprising results bearing on the effect of the weight and design of truck and tire equipment on the impact on the road surface.

The curves of pressure shown in Fig. 3 apply, of course, to only one particular case, that of an 8-ft. concrete road supported on a rather wet subgrade of poor supporting value. It will be readily understood that if the concrete slab had been of different thickness or if the subgrade material had been harder or softer, the curves of pressure would have had somewhat different values, although the general relations shown by these curves would have remained practically the same. It will likewise be understood that a pavement with slab strength is more likely to distribute the heavy loads over a wider area on the subgrade than pavements having no slab strength, and that at the same time the maximum intensity of pressure under such pavements would be smaller than that under a pavement of the latter type if the thickness of the two pavements were the same. A pavement having no slab strength can be made to distribute heavy wheel concentrations to the subgrade, however, by merely increasing its thickness. We have seen in the tests just cited that the maximum intensity of pressure on the subgrade due to a wheel load of only 8500 lb. is equal to 6½ lb. per sq. in. This seems like a very small pressure, but even this pressure is very much more than some subgrades are able to support, and this is by no means the highest pressure to which the subgrade may be subjected, for some pavements must carry wheel loads of 15,000 lb., not at rest but moving and therefore applied with impact.

Soft Subgrades

Suppose the subgrade is so soft that it yields considerably even under so light a pressure as 6½ lb. per sq. in.; under such conditions the pavement is offered very little support by the subgrade and directly under the load a high stress is produced in the pavement if it is distorted thereby to a great extent, and failure is likely to result. It goes without saying, then, that the ideal condition of the subgrade is one in which the greatest possible support is offered to the pavement. One does not have to make many field investigations to assure oneself that invariably water is the primary cause of all soft subgrades, but it is not so easy a matter to ascertain to what extent water decreases the bearing value of the wide range of soils encountered. Nor is it easy to specify the best method for getting rid of the water from soils of different types. It has been observed in very many road failures that the subgrade consists of a sticky plastic clay that takes up enormous quantities of water when saturated and becomes very soft in its saturated condition. It has likewise been a matter of general observation that soils of the more porous types, such as sands and gravelly soils, are much more likely to have low bearing value under the continued action of water. Soils are graded between these extremes and no doubt their bearing value varies with the physical characteristics of the soils.

It must not be thought that heavy loads and soft subgrades are alone responsible for our road failures. We have all seen the large shrinkage cracks produced in soils of a clayey nature when they have been baked in the sun. If they will shrink to such an extent as to cause cracking, is it not reasonable that when they are again soaked with water they will show a correspondingly large expansion? And since this expansion takes place in a non-uniform manner, is it not clear that the pavement will be given non-uniform support? Moreover, it is important that we do not forget the action of frost. We are all familiar with the volume expansion produced in water as it freezes and when the subgrade is saturated and subjected to frost action, and we know that vertical expansion takes place, which in many cases produces cracking of the pavement by virtue of the inequality of this expansion in different places in the road.

All of us have observed the extreme hardness of many soils when they are perfectly dry, and no laboratory tests are needed to tell us that these same soils when they are made wetter and wetter become softer and softer and finally lose all ability to support loads. It goes without saying that one of our main subgrade problems is that of successfully getting rid of a sufficient quantity of water from the subgrade to render it of high enough bearing value that pressures produced upon it will never

[2] See The Distribution of Pressures through Earth Fills by A. T. Goldbeck. *Proceedings of the American Society for Testing Materials*, 1917.

be excessive. Our aim should be always to have the bearing value of the soil exceed the maximum pressure produced on the soil by the loads on the pavements. It happens that certain types of soil are extremely difficult to drain, using methods which are successful in other types. It has been found that tile drains that are very successful in some types of soil will do nothing more than reduce the moisture content for a few feet surrounding the drain in other types.

The Drainage Problem

One of the problems before us today is to determine the physical characteristics of soils that are susceptible of drainage treatment of a particular kind. How many engineers would think of using a soil auger in a preliminary survey of the proposed site of a new road? Yet there is no doubt that by taking borings and obtaining samples of the soil at different depths much light will be thrown on the character of support that will be offered by the subgrade and on the possibility of water being retained by the subgrade. It has been observed in several cases where failure of the road has resulted, that 2 or 3 ft. below the subgrade there was an impervious stratum which retained the water in the upper layers and kept it saturated in the spring of the year. Borings will often reveal the presence of a seepage stratum carrying continually flowing water which should be diverted from the road subgrade. These points are cited to show that the subgrade problem involves much field study as well as the mere study of the soils in the laboratory.

To reduce the water content in the subgrade to a safe minimum, drainage systems will no doubt be needed which in many cases will be very costly. Our subgrade problem is being taken up to lead us to the adequate and economical design of the road. Let us not forget that the road structure involves the subgrade as well as the wearing surface. By strengthening either we strengthen the entire structure. We can, perhaps, cheapen the road surface by strengthening the subgrade, but the strengthening of the subgrade may involve an extraordinary expense and for this reason we must not forget that we may be able in some cases to accomplish our end by

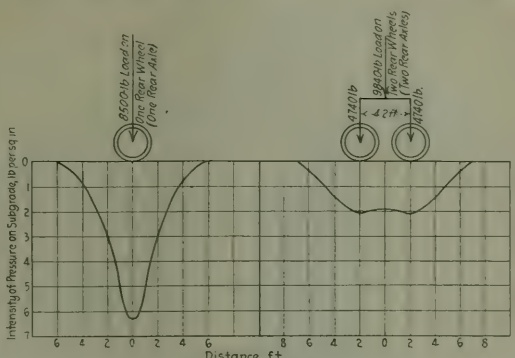

8500 lb Load on One Rear Wheel (One Rear Axle)
9800 lb Load on Two Rear Wheels (Two Rear Axles)
4740 lb
4740 lb
4.27 ft.
Intensity of Pressure on Subgrade, lb per sq in
Distance, ft

Fig. 3—Curves Showing the Intensity of Pressure Transmitted to the Subgrade through an 8-In. Concrete Slab

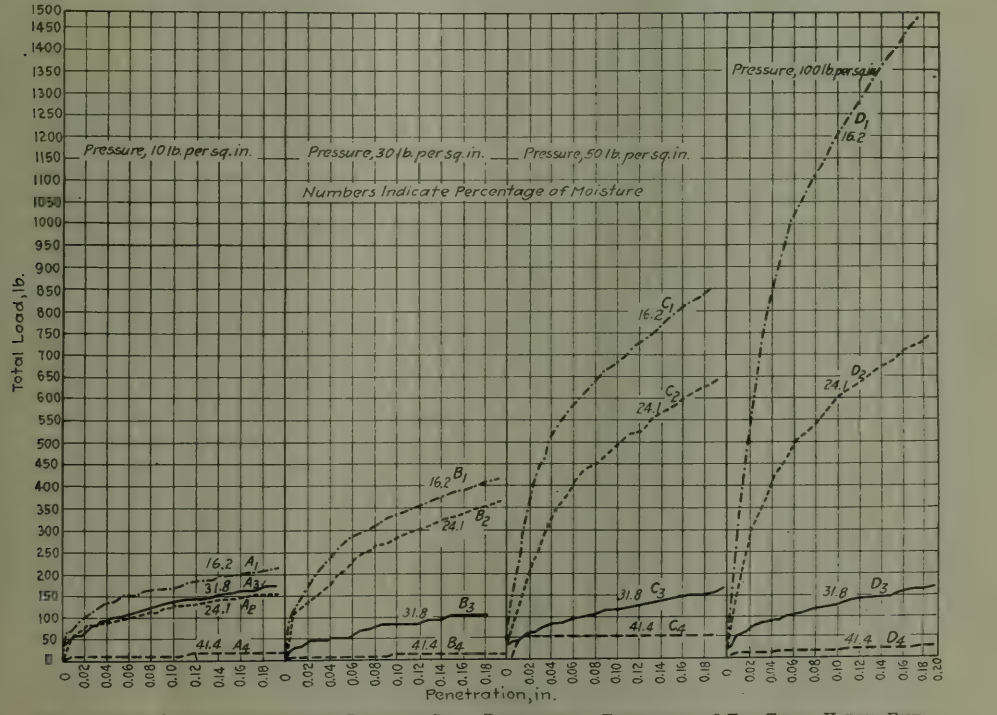


Fig. 2—Chart Showing the Bearing Power of Soils Based upon a Test with a 5-Ton Truck Having Four Rear Wheels

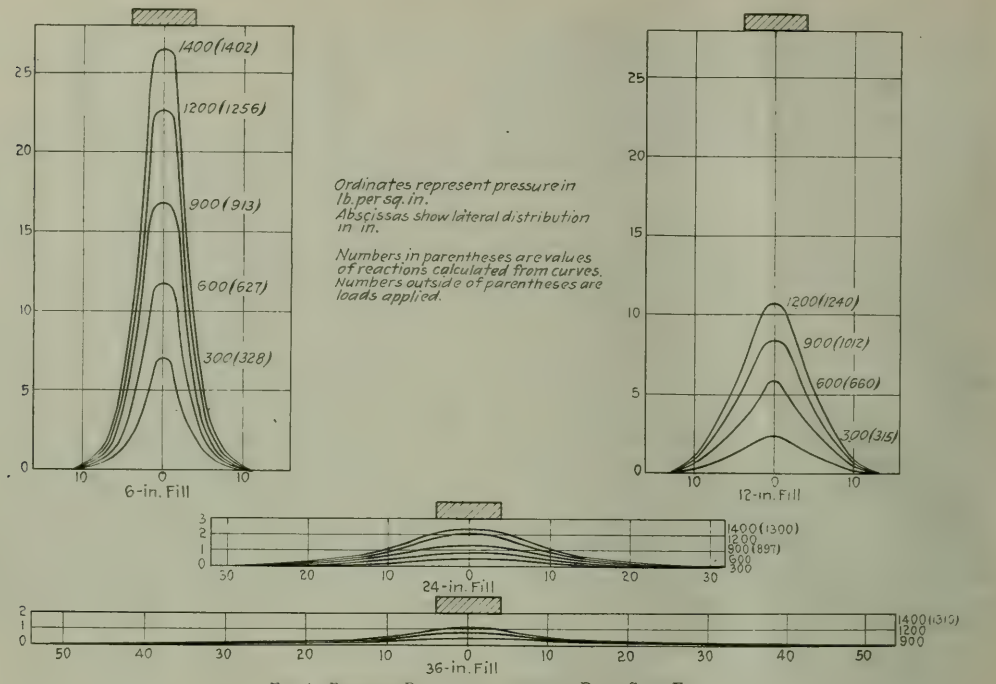


Fig. 4—Pressure Distribution through Damp Sand Fills

strengthening the road surface to the neglect of the subgrade. These are questions of economy to work out when we know more of the methods for treating subgrade materials.

We have spoken of attempting to increase the bearing value of the subgrade by getting rid of the water, but there may be other means for accomplishing the same end. A few years ago a study was made of the manner in which heavy pressures are distributed through fills of different thickness. A typical set of curves showing this distribution is given in Fig. 4. The point to be noticed is that at very shallow depths there is high intensity of pressure and that the deeper the fill the lower becomes the intensity and the wider the area over which the pressure is distributed. This fact is significant, for it shows that if under the wearing surface of a pavement we provide a layer of material having high bearing value, then by virtue of an extra thickness of material the pressure intensity on the underlying soft subgrade may be so much reduced as to keep it below the bearing value of the soil. It is not impossible that some chemical means will be developed for changing the characteristics of soils having low bearing value, although no suitable means have thus far suggested themselves. It is likewise not impossible that by satisfactorily waterproofing the subgrade for a certain depth we can produce a waterproofed layer of material of high bearing value which will serve to distribute pressures to the soft subgrade beneath.

Laboratory Investigations of Subgrades

All of the preceding points are subjects for investigation and at the present time a very definite scheme of investigation of subgrades is being followed out by the Bureau of Public Roads and by other laboratories interested in these problems. Not only have investigations including field and laboratory tests been made but special drainage researches are being carried out on a large scale in the field. Some time ago a memorandum was sent to our various Federal district engineers throughout the country asking them to assign men to make special observations on roads that had failed due to soft subgrades and heavy loads. Complete data with regard to these failures were supplied, including a description of the failure, topography of the country, the condition of the drainage system, if any, photographs of the failure, the character of the traffic and in fact all information that could be obtained in the field regarding the cause of the failure. In addition, borings were taken with a soil auger in general to a depth of 5 ft., to determine whether there was any change in character of the soil at different depths, thus furnishing information as to the probable reason for the presence of large amounts of water near the surface. Large samples of the soil were obtained from those spots in the road that had failed and samples of this kind have been shipped to Washington from all over the country. Corresponding observations and samples of material have been taken from sections of some of the same roads that have not failed. We are now subjecting these samples to a number of physical tests and we hope to be able to throw light on some of the questions involved. The samples are being subjected to the following tests:

(1) Percentage of clay and of silt
(2) Mechanical analysis
(3) Slaking value
(4) Cementing value
(5) Compressive strength
(6) Bearing value

(7) Specific gravity
(8) Percentage of water retained by capillarity
(9) Moisture equivalent
(10) Colloidal content, etc.

In the present paper it will obviously be impossible to go into a description of all the methods pursued in these physical investigations, nor will such detail be necessary. These methods are described in a publication which will shortly be issued by the Bureau of Public Roads. It will be well, however, to point out the results obtained on a few samples examined, for these have already shown why roads have failed on certain types of soil and stood up well on other types. The results which are thus far most significant are the results of the bearing value test. To understand them it will be necessary to describe briefly the methods being followed in making this test. In the natural subgrade of a road soils are subjected to extremely varying conditions. At times they are saturated and again they may be perfectly dry. Sometimes they are expanded through ice action and are thoroughly saturated with moisture in that condition. They may be thoroughly compacted in either a dry or a wet condition. It has been thought necessary to attempt to simulate field conditions in the laboratory, and this is the basis of our present procedure.

The sample of soil is broken up in a mortar by a rubber-covered pestle, care being taken not to break any of the rock fragments. It is then passed through a ¼-in. screen. That portion passing this screen is then run through several rubber rolls to pulverize the soil without grinding it. The pulverized soil and the coarser materials are then combined and thoroughly mixed.

Bearing Value Test

The first consideration in making the bearing value test is to determine the range through which the moisture content should be varied. The lowest percentage of moisture is determined by the workability of the soil, that is, just enough water is added to the sample to enable it to be thoroughly mixed and placed in the small mold homogeneously. The maximum percentage should be that which corresponds to the saturation point of the soil. This is determined by the percentage of water the soil will take up by capillarity when loosely compacted. Two intermediate percentages of moisture are taken such that the interval between the four percentages is about the same.

The second consideration is the application of initial pressure which determines the compaction of the soil. Tentative initial pressures of 10, 30, 50 and 100 lb. per sq. in. are being used. The complete bearing value test on a sample of soil consists, therefore, of tests with the soil having different percentages of moisture and different applied initial pressures.

Having pulverized the sample, it is mixed with the smallest quantity of water to be used in the series of tests. The sample is kneaded with the hands, protected by rubber gloves, and then placed in a cast-iron cylinder 6 in. in diameter and 6 in. high. The plunger is then placed in the cylinder and the soil compressed in the testing machine under a definite pressure for a period of

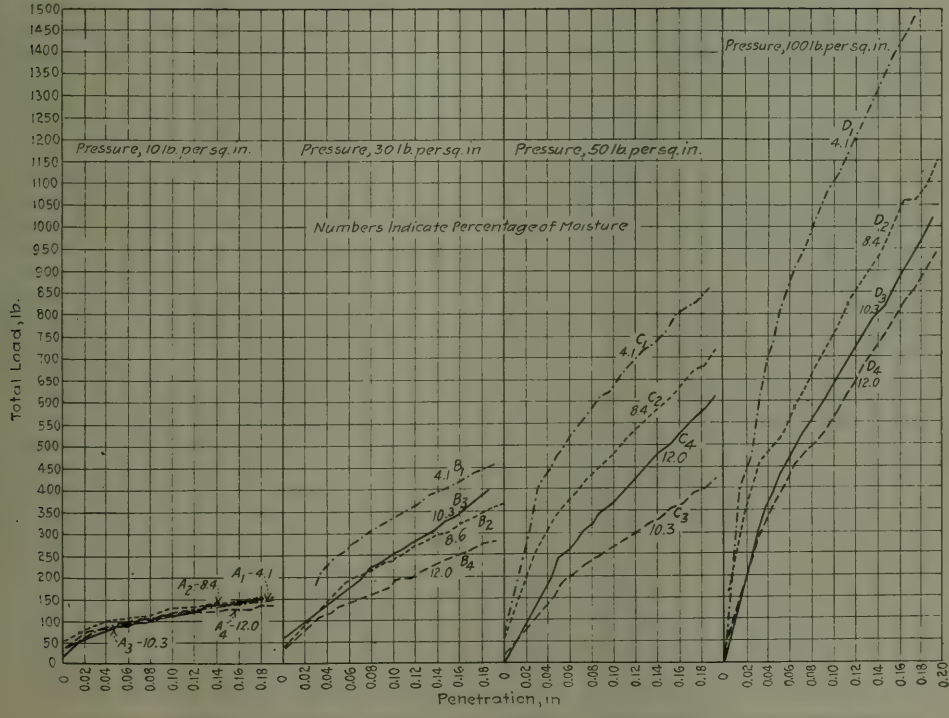


Fig. 5—Chart Showing the Bearing Power of a Soil Composed of 25 Per Cent Clay and 75 Per Cent Sand

5 min. Having subjected the sample to initial compression, the plunger is removed and a circular bearing block placed on top of the specimen; a pressure is again applied at the slowest speed of the testing machine and simultaneous readings are taken of the pressure applied and of the penetration of the plunger. The penetrations are obtained by Ames dials, reading to 0.001 in. Having completed a bearing value test with the smallest initial compression of the sample, the soil is removed from the plunger and replaced and subjected to another initial compression, and the bearing value test is repeated.

When the sample has been tested when prepared with the four initial compressions outlined above, more water is added and thoroughly mixed, and bearing value tests are again run with the soil in the wetter condition. Finally, the test is run with the soil having the highest percentage of water mixed with it that a loose sample will take up by capillarity. It will be seen that by performing the test in this way the bearing value is obtained with the soil prepared artificially, much in the same way that it is prepared by nature in that it is subjected to a range of moisture content and a range of compaction.

It is not my wish to enter into a detailed discussion of the results at the present time. I should like, however, to point out certain indications obtained with two soils having considerably different characteristics. It has been stated that observation tells us to expect trouble from road failures in the spring of the year when the subgrade is thoroughly saturated with water. In judging of the bearing value of a soil we should therefore judge it by its saturated condition. The soil shown in Fig. 2 is adobe soil and comes from a road that failed very badly. It should be noticed that this soil absorbed 42 per cent by weight of water when saturated and also that when it was saturated, no matter whether it received an initial compression of 10 lb. per sq. in. as in curves *A*, or 100 lb. per sq. in. as in curves *D*, its bearing value was exceedingly low. In fact, judging from the curves it would seem that in a saturated condition this soil would support a load of barely 2 lb. per sq. in. and under this load there would be continued sinking. A special sand-clay mixture, on the other hand, composed of 75 per cent of coarse sand and 25 per cent of clay, as shown in Fig. 5, absorbed only 16 per cent of water by weight of dry sample when it was saturated, and it will be observed that the curves of bearing value show considerably higher ability to support loads than in the case of the adobe soil. It will be seen also from these curves that soils of this character having a higher percentage of coarsely granular material when densely compacted have a higher bearing value than when loosely compacted even though the soil is saturated. This is unlike the exceedingly finely divided adobe soil. It will be noticed in addition that the sand-clay when saturated has considerably higher bearing value than adobe when both are saturated.

Attention was called to the pressures obtained by actual measurement under an 8500-lb. wheel load on the Camp Humphreys 8-in. concrete road, the pressure there being 6½ lb. per sq. in. due to this load. The bearing value test on the adobe soil shows it to have a maximum resistance, when saturated, of only 2 lb. per sq. in. Is it necessary to proceed any further to show why certain roads laid on certain types of soil have failed utterly? Would we think of designing the footing for a building in such a way as to produce greater pressure on the soil than the supporting value of the soil under that footing? Yet, that very thing is being done in the case of roads laid on certain types of soil, and naturally the soils yield with the distortion of the road surface. Before leaving the curves just described, it is interesting to note the exceedingly high bearing value to be expected even from adobe when it has a low percentage of moisture and it is tightly compacted. Such values are shown by curve *D*. This, of course, bears out our common experience that even the worst kind of clay soil will support heavy loads so long as it is dry and compact.

I do not wish to give the impression that we have proceeded far enough with our investigations to say what physical characteristics soils must possess to render them of high bearing value. I do feel, however, that we are gradually obtaining results which in the end will give us this information. It seems that our results point to the conclusion that finely grained and exceedingly plastic soils, when saturated, are likely to give a considerable amount of trouble and that the coarsely grained, more porous soils which drain well and have a high bearing value will give the least trouble. There is a gradation, however, between these types and it is our aim to couple the bearing value of these gradations with the physical characteristics and likewise with the possibility of these different soils being drained by various systems of drainage.

Drainage Investigations

No soil investigation would be complete without a study of methods for adequately draining the subgrade. It is well known that many roads have failed on fills as well as in cuts when the soil has been of a particular type; also that some soils are not susceptible to drainage such as might be used on other types. We have seen subgrade failures throughout the country where drainage was employed. We have ever before us the constant example of city pavements of comparatively light cross-section very successfully carrying extremely heavy loads, and we are forced to the conclusion that perhaps many of our so-called drainage systems are not as immediately effective as they should be at the time when most needed, in the spring of the year.

Our curiosity has been aroused as to whether some sort of drainage system that will exclude the water from the subgrade should not be designed. Our present drainage systems, it would seem, are built to carry the water away from the subgrade after it has had a chance to make the soil thoroughly wet and soft. In Fig. 6 will be observed a series of drainage experiments which has been started at Arlington Farm in an effort to determine some principles underlying the drainage of subgrades. This, in itself, is a big subject and cannot be covered in the time allotted. I have mentioned the effect expected from waterproofing the subgrade and the action of the sub-base of porous materials, both of these methods having the effect of decreasing the intensity of pressure on the soft underlying subgrade. Some of the other sections, it will be noticed, aim to exclude the water by impervious walls built along the slab. If these experiments prove successful, we hope to carry them out on a large scale with the aid of the State highway departments. Our criterion of success is the percentage of moisture in the subgrades under the various experimental sections. We take samples of the soil under these slabs through openings in the slabs and that section showing the driest subgrade may be considered as most effective. By next spring we shall know if any of the schemes is of value. In conclusion, I want to point out that the amount of research to be performed in connection with highways is almost unlimited. I have spoken of only one phase.

As some of you probably know, we have been looking

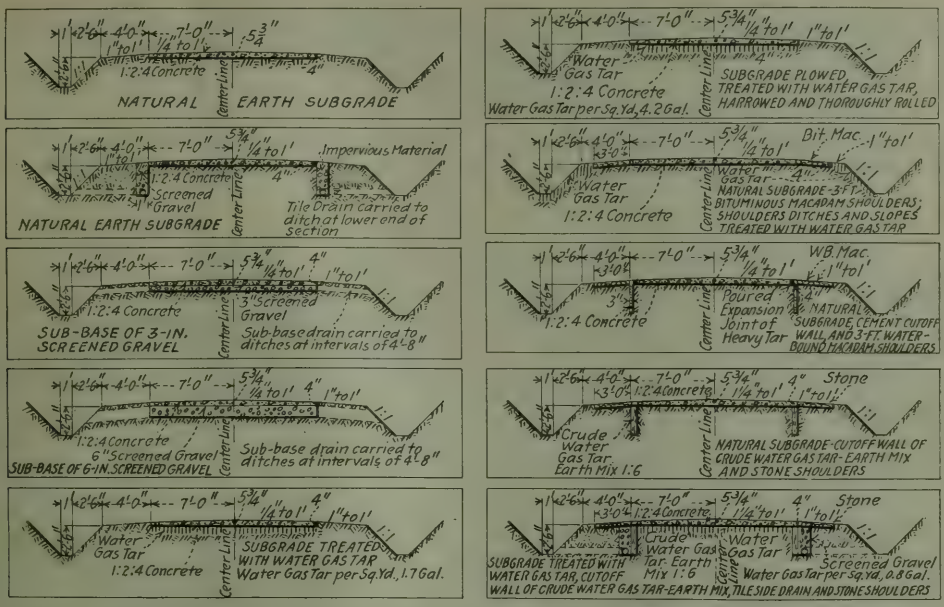

NATURAL EARTH SUBGRADE
1:2:4 Concrete
Center Line
SUBGRADE PLOWED, TREATED WITH WATER GAS TAR, HARROWED AND THOROUGHLY ROLLED
Water Gas Tar
1:2:4 Concrete
Water Gas Tar per Sq. Yd., 4.2 Gal.
Impervious Material
Screened Gravel
Tile Drain carried to ditch at lower end of section
NATURAL EARTH SUBGRADE
Bit. Mac.
NATURAL SUBGRADE-3 FT. BITUMINOUS MACADAM SHOULDERS; SHOULDERS DITCHES AND SLOPES TREATED WITH WATER GAS TAR
SUB-BASE OF 3-IN. SCREENED GRAVEL
3" Screened Gravel
Sub-base drain carried to ditches at intervals of 4'-8"
W.B. Mac.
Poured Expansion Joint of Heavy Tar
NATURAL SUBGRADE, CEMENT CUTOFF WALL, AND 3-FT. WATER-BOUND MACADAM SHOULDERS
6" Screened Gravel
SUB-BASE OF 6-IN. SCREENED GRAVEL
Stone
Crude Water Gas Tar Earth Mix 1:6
NATURAL SUBGRADE-CUTOFF WALL OF CRUDE WATER GAS TAR-EARTH MIX AND STONE SHOULDERS
SUBGRADE TREATED WITH WATER GAS TAR, CUTOFF WALL OF CRUDE WATER GAS TAR-EARTH MIX, TILE SIDE DRAIN AND STONE SHOULDERS
Water Gas Tar per Sq. Yd., 0.8 Gal.

FIG. 6—VARIOUS FORMS OF ROAD CONSTRUCTION WHICH HAVE BEEN TESTED AT THE ARLINGTON FARM OF THE BUREAU OF PUBLIC ROADS TO DETERMINE THE PRINCIPLES UNDERLYING THE DRAINAGE OF SUBGRADES

into a number of different phases of research, seeking for light on the design of roads to carry heavy trucks adequately. We feel that we have discovered a number of fundamental facts with relation to the impact effects of motor vehicles on roads and if I had the time I could no doubt show you some very interesting data bearing on the subject of weight and design of motor trucks and the different effects of tires.

We have also looked into the subject of the effect of heavy impacts on road surfaces of different types and I wish to call your attention briefly to the curves shown in Fig. 7. These represent results obtained by subjecting slabs of concrete laid on a wet subgrade to impact, an impact exactly like that delivered by the rear wheels of a 5-in. truck. The slabs were 4, 6, 8 and 10 in. in thickness, respectively. We have broken every slab on a wet subgrade except those 10 in. in thickness, and our specimens were not tested with the load applied in the most disadvantageous position but rather in the position most favorable to the slab. The 4-in. slab broke under 634 blows; the 6-in. under 1239 bows, the 8-in. under 2552 blows; and the 10-in. slab was subjected to 6000 blows without any signs of failure. The curves show directly how much difference in strength there is between a 4 and a 10-in slab.

One of our most important problems is to determine whether we cannot obtain satisfactory strength with a comparatively thin slab, provided the subgrade is maintained in satisfactory condition. I mention these experiments in connection with the subgrade experiments merely to give you some idea of some of our problems. The amount of money contemplated for expenditure and actually being expended at the present on road construction is enormous. The day is past for building roads of de-

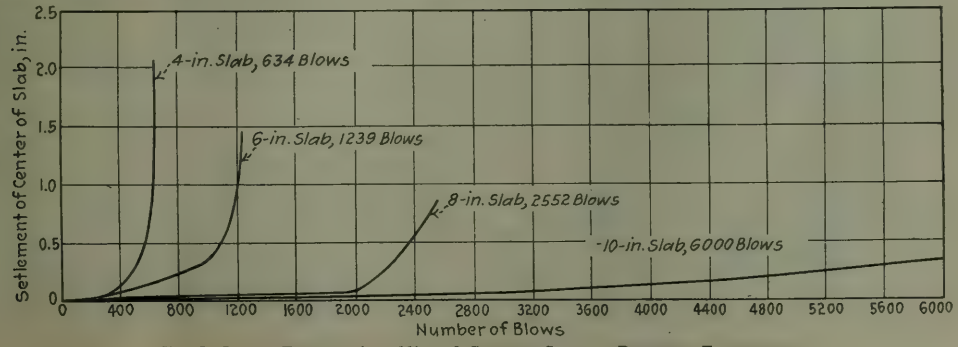


FIG. 7—IMPACT TESTS ON 1 TO 1½ TO 3 CONCRETE SLABS OF DIFFERENT THICKNESSES

signs arrived at by rule-of-thumb. Our future designs must be based on sound, scientific, fundamental data. There is too much money involved to have it otherwise. It is our duty to expend this money in such a way that our road structures will give us the most economical service. It is the duty of those having to do with highway transportation, and this involves the truck designer as well as the road engineer, to see that the public supplying the funds get the greatest possible benefit.

Is it not manifest that road engineers and automotive engineers must meet in joint conferences to the end that road design and motor-truck design shall be mutually adapted one to the other; and to the end that these designs shall be governed with the goal very clearly in mind, that of ultimate economy in cost of haul? Ultimate economy includes motor-truck economy as well as road economy and many perplexing technical and economic problems will confront such a conference.

WHAT IS A MACHINE TOOL?

EDWARD H. KNIGHT in his mechanical dictionary, published in 1872, gives the following definitions: *"Machine:* An instrument of lower grade than an engine, its motor being separate. It is distinct from a tool, as it contains within itself its own guide for operation. *Machine Tool:* A machine in which the tool is directed by guides and automatic appliances. Among tools of this class for metals are lathes, punches, and shears. Machine tools for wood are sawing machines, planing machines, etc." It is the habit of dictionary makers to copy each other, and it is not improbable that our present-day dictionary interpretation of the word is derived from the above. It must also be said that to define a machine tool as a tool-using machine is very natural. There is some doubt, however, if the original and common use of the words is as indicated above. Cameron Knight, author of The Mechanician and Constructor, published in 1869, in the course of a very complete definition of shop terms, includes the following: "Tools include every implement small and large, simple or complex, which is used to produce or operate upon the work in the course of progress. A center-punch in a turner's pocket is a tool, and the lathe before him is a tool."

It is an easily verified fact that in the text and advertising columns of the early mechanical papers such as the *Scientific American* (1846), the *Mechanics' Magazine* (1836), and the *American Artizan* (1862), the term "machine tools" is used but seldom, and then exclusively by editorial writers. The first observed use was in 1862. "Tools" is the word that was in universal use throughout the Civil War period to indicate what we now call machine tools. Advertisements for the sale of the after-war surplus were either under this caption or under the heading "machinist's tools." This use of the word persisted into the eighties. In 1879 Frederic B. Miles formed a company with the name "Machine Tool Works." This is the first noted instance of the use of this term by a shopman. The company advertised the building of steam hammers, planing machines and lathes.

On first thought we may be inclined to define a machinist as a machine-using workman, and a machine shop as a machine-using shop, but this definition will admit weavers and textile mills to these classifications. It is evident that a machinist is a machine-*building* workman, and a machine shop is a shop that *builds* machinery. By analogous reasoning a machine tool is not a tool-using machine, but a machine-building tool; that is, a tool or machine for building machinery. This conforms to the best modern definition of the term, namely, "Machine tools are machines which, when taken as a group, will reproduce themselves." This definition has the disadvantage of being general rather than specific. As a secondary definition the following might be suggested: "A machine tool is any metal-working tool the waste from which is in the form of chips." This is specific and can be easily applied to any particular machine. It is not necessary to define a metal "chip," but it may be advisable to recall that the sparks from a grinding machine are chips. This definition excludes sheet-metal working machinery and metal-forming and forging machines, but these are probably not classed as machine tools by the majority of shopmen. In any case it is necessary to draw the line somewhere, and this seems to be the best place. This classification includes all metal-cutting machinery the action of which is a progressive cutting away of surplus stock; a gradual reduction in size until the finished dimensions are reached.

A press used for piercing sheet metal has very little in common with a lathe, a milling machine or a planing machine. They are all metal-cutting machines, but there the similarity ceases. When a press is used for forming it has nothing in common with lathes, etc., other than the fact that they are all metal-*working* machines, as are also power hammers, bulldozers, swaging machines, etc.—*Machinery.*

THE NEW S. A. E. HANDBOOK

THE revised edition of Vol. 1 of the S. A. E. HANDBOOK has been sent to all of the members of the Society. Members who have failed to receive their copy should communicate with the Society.

In using the revised Handbook the page number on which a standard is printed may be found by looking up

(1) The principal noun of the subject in the general index on page K45

(2) The subject in the proper Section of the table of contents on page v

(3) The standard direct in the proper Section

If it is desired to find out what standards have been approved for use in the different automotive industries, the key system in the table of contents may be used. For instance, standards applicable to tractor engineering have a capital T at the right of the page number under the heading "Practice."

Sections which are of no interest to a member can be removed as each Section with the general matter on pages i to xiv and the index on pages K45 to K55 makes a self-contained book.

Blank data sheets which can be purchased at any stationery store can be inserted and used as memorandum sheets.

The complete Division report or reports on each S. A. E. Standard and Recommended Practice can be found in the TRANSACTIONS of the Society by referring to the volumes for the periods corresponding to the adoption and revision dates in the footnotes appearing at the end of each standard. For example, reports referring to a standard adopted in March, 1913, and revised in August, 1915, will be found in the TRANSACTIONS for the first half of 1913 and second half of 1915 respectively commencing as a general rule on page 2.

Aerial Transportation as a Business Proposition

By Glenn L. Martin[1]

Annual Meeting Paper

AERIAL transportation includes the use of airships as well as airplanes, but in this paper I will confine my discussion principally to the commercial use of the airplane as a vehicle of transportation. In discussing the subject of aerial transportation, one is apt to lapse into analogies and comparisons with the railroad, the motor truck or the steamship, but as a matter of fact aviation has no perfect analogy, for it has no precedent. There is much that can be learned from railroad, motor-truck and steamship transportation that is helpful in aerial transportation, but the man who thinks he can apply the same rules to commercial aviation will arrive at a very sad misunderstanding.

Aerial transportation is a wholly new business, unlike any other form of transportation. It is a new industry which is really in its embryonic stage, an industry that demands high standards of personal efficiency in the men who are engaged in it. In considering the function of aerial transportation, let us, for the sake of clearness, divide it into two distinct classifications; scheduled service and special service. By the first I mean the carrying of mail, express or passengers on a definite and regularly maintained schedule, independent of or supplementary to other forms of transportation. Special service includes pleasure flights, oil-field survey, selecting industrial land-sites, planning cities, aerial photography, forest fire patrol, visiting remote points, exploration, aerial advertising, delivery of perishable products, real estate survey and industrial purposes.

The Two Classes of Service

It is to be understood that each of these two classifications of aerial transportation requires different equipment, organization and operating personnel. A scheduled service, to be of true commercial value, must be faster than any competing form of transportation and operate on schedule. Aircraft capable of at least 100 m.p.h. are therefore essential, and flights must be conducted regardless of weather conditions. Weight-carrying capacity must be sacrificed for greater speed. Since the efficiency of a service of this nature requires the very best design of aircraft, operated by a highly efficient personnel, rates naturally must be high. A scheduled service, properly organized and efficiently operated in stages of from 300 to 500 miles, should average at least 80 m.p.h. in spite of wind and weather conditions.

The most striking example of this class of service is the London-Paris Air Express. The company operating this closed its first year's service on Aug. 25, 1920, with a record of 323,355 miles flown at an average speed of 100 m.p.h. Of the 1535 flights scheduled for the year, 1448 were finished *on time*, while 83 were prevented by weather and four trips were delayed by mechanical defects but were later completed after repairs had been made. Harry Harper, technical secretary of the Civil Aerial Transport Committee in England, declares that one should lay stress on the fact that the conditions for flying are probably worse on this particular route than almost anywhere else in the densely inhabited parts of the world. Yet in spite of this weather handicap the London-Paris Air Express has an efficiency record of 94 per cent for the first year of service.

A special service does not make such high demands as a scheduled service. Speed is not so highly important and the weight-carrying capacity can therefore be increased considerably. Moreover, the maintenance of a schedule is unnecessary, and as for weather conditions it is quite possible to wait for weather. Before the day of the airplane the forest ranger was the sole means of detecting forest fires. His means of locomotion was his horse, and usually he was unable to report a fire until the conflagration had gained headway and thousands of dollars were lost before any combative measures could be taken. During 1919, it has been estimated, approximately 2,900,000 acres of National Forest lands were destroyed by fire; the damage represented a net loss of $4,500,000 and a cost to the Forest Service of $3,000,000 for fighting fires. Forest fires are now located by airplane. The picturesque figure of the forest ranger, riding furiously on horseback to give the alarm, is a thing of the past. Since the establishment of the Aerial Forest Patrol on June 1, 1920, the fire hazard has been practically eliminated. Seventeen airplanes were used for fire patrol work. They covered 235,724 miles in 2872 hr. and were instrumental in putting out 570 fires in California and Oregon. There was only one fatality on all these patrols, and only eight accidents necessitated major repairs on the planes.

Scheduled service and special service have one basic problem in common, the distance it is profitable to fly without landing for refueling. It is quite clear mathematically that a cruising radius or operation stage of over 500 miles for an airplane demands the carrying of a large amount of fuel at a great expense and sacrifice to cargo capacity. Airplanes at the present time are short-distance vehicles. Their prime advantages over airships are their speed and flexibility. Where long nonstop flights of 1000 miles and more are required, the airship, with its greater lifting capacity is, of course, decidedly more suitable. Where long-distance flights are required of airplanes, landings should be made every 300 to 500 miles for refueling. Thus it is obvious that airplanes and airships are in no way rivals at present.

Reliability of Air Transportation

Many business men believe that, from a business point of view, aerial transportation is unreliable as well as extremely expensive. Any unreliability that may exist in aerial transportation is dependent upon three factors.

(1) The operating personnel
(2) The airworthiness
(3) The weather conditions

In railroad, motor-truck and steamship transportation

[1] M.S.A.E.—President and general manager, Glenn L. Martin Co., Cleveland.

many mistakes which are errors of the personnel or its faulty organization, causing accidents or delay, get by the press with only a stick of type. Most cases are even unnoticed. In aerial transportation the story of one interrupted flight, if it results in an accident, is published in bold-face type from coast to coast. Without federal legislation operating personnel and ground organizations which are wholly incompetent to operate successfully will be hurriedly put together, even though the airplane equipment is of the best. The administrative force should be composed of men who speak and think in the language of aeronautics. With the proper organization and administration of pilots and mechanicians, there is no doubt that personal error can be reduced to a low minimum.

In considering the airworthiness of an airplane as the basic unit of aerial transportation, it is well known that until recently airplanes employed in commercial service were discarded war material, unsuitable for civil purposes. Today, however, the designing and construction of both engines and airplanes have reached such a high state of commercial adaptability that with proper organization and maintenance mechanical breakdown should seldom, if ever, occur. I do not say that the commercial airplane has reached the acme of perfection, for there is yet much to be accomplished in the improvement of both airplanes and airships. Nevertheless, the London-Paris Express Service has flown over 300,000 miles, often under conditions that have imposed severe strains on the machines as well as on the pilots, with only four interruptions caused by mechanical defects.

Weather conditions are a factor in aerial transportation over which the operative personnel had, until recently, very little direct control. In the early days of flying no aviator would think of flying in wind or storms; a perfectly calm day was necessary before he would soar into the atmosphere. In those days, of course, the airplane would not weather wind and storm, but the modern airplane will fly through wind, storm, rain or snow. There are two elements, however, which must be conquered, low clouds or fog and darkness. The difficulties involved are the possibility of losing the course of flight and the chance of misjudgment in landing. Airplanes and airships are now being fitted with directional wireless by which the pilot can ascertain his exact position at all times. Within a reasonable period of time night flying will be as common as day flying, fog and low-cloud hazards being negligible.

Terminals

With the very best design of commercial airplane and the most highly efficient organization and administration, aerial transportation can go no further than its terminals. The need for aerial terminals, municipal airdromes, is acute in the United States. The builders are producing airplanes; the engineers are working on improved types of commercial planes; transportation companies are organizing all over the country, and yet to what avail? Aerial transportation will never become universal until each and every community provides an air terminal equipped with proper facilities. Communication by wireless, telephone and telegraph should be provided, as well as rail and motor-vehicle transportation for passengers and freight, hangar accommodations, repair service and stores, gasoline, oil and sundry supplies. The progressive cities in the United States have already awakened to the fact, and I am sure the laggers would follow suit if they only realized that they are mortgaging their future by failing to grasp the tremendous advantage of being on the "main air-line." What would Chicago be, for example, if she had not been the first to recognize the possibilities of her geographical situation? A mere hamlet, or perhaps a port of minor importance. Chicago did not let opportunity knock unanswered at her door. She developed her harbor facilities and is now the biggest port on the Great Lakes, and the second largest city in the country. In the same way aerial navigation will transform many an unimportant village and bring towns out of humble obscurity into the limelight of commercial prominence.

Federal Flying Regulations

The next point I want to take up is the need of federal flying regulations. America has not yet made a beginning in this direction. Several State legislatures have passed laws providing for the regulation of air traffic within their borders, but the range of the airplane is so unlimited that the legislation of a great number of individual States would lead merely to hopeless confusion. Federal legislation is the only solution. It should not only regulate aerial traffic but provide uniform regulations for licensing pilots and aircraft, and periodic inspection of aircraft and landing fields. Other forms of transportation are inspected. Our steamship and railroad lines are made to conform with certain standards of safety before they are allowed to carry passengers; why not aircraft? Pilots entering or taking-off from any airdrome should be required to adhere rigidly to the rules and regulations. "Stunt" flying should be forbidden, even at the risk of making flying as devoid of thrills as riding on a freight train. Many lives have been sacrificed for the sake of a thrill. Provisions should be made for the adjustment of claims for injury or damages to persons or property resulting from the operation of aircraft, whether licensed or not, and these provisions should be so strict in covering the determination of responsibility for accidents that aerial transportation companies or other agencies directly concerned would not hesitate to assume the liabilities that might be incurred in operating commercial aircraft. England has recognized the necessity of federal legislation. No airplanes are allowed to fly over an English city except at a height which permits them to glide beyond the city limits in case of trouble. Heavy fines are imposed for "stunting."

Insurance

There is one phase of the aeronautical industry in which America leads the European nations, aircraft insurance. We have in the United States an organization known as the National Aircraft Underwriters Association which collects and publishes hazard statistics. These data form the basis on which insurance companies make out their policies. Today there are numerous insurance companies which issue policies to owners of aircraft. The premium is based on three determining factors, (*a*) the pilot's efficiency record, (*b*) the type of plane and its performance record and (*c*) the type of engine. The Underwriters Laboratories is planning to go into this matter more intensively. The examination of aircraft is to be conducted in the same manner as automobiles and electrical supplies are inspected. This will have a double advantage, for it will not only furnish the various insurance companies with further reliable data but give the builder some assurance that the purchaser can get insurance on his airplane. Few business men care to sink money in an enterprise that is not fully protected against accidental losses. The very fact that transportation companies in the United States can take out insurance on

their planes will probably do more to put commercial aviation "on the map" than any other single development along business lines.

Development of Commercial Transportation

Civilian aerial transportation had its birth in England in May, 1919. Germany followed closely with similar enterprises. The beginning was not very auspicious, for neither the aircraft industry nor the public was ready for commercial aviation. England's national exchequer was exhausted, her industrial system had collapsed, and yet in spite of these insurmountable obstacles commercial aviation grew and advanced. No preparations were made beyond converting a few war machines into carriers. There were no large national appropriations to promote this new method of transportation. On all sides the project contended with the skepticism of the financial wizards and the instinctive conservatism of the masses. England opened up the first continental air-route between London and Paris. Within an almost incredibly short time routes from London to Brussels, Lille and Amsterdam sprang into existence, as well as interior routes to all the principal cities in the British Isles.

While Germany was not in a position to encourage commercial aviation, German private enterprises flourished. Air-lines from Friederichshafen to Berlin were opened, using flying-boats and huge airplanes. France and Italy are now doing their best to make up for lost time. An aerial line for passengers between the French capital and Strasburg has just been instituted. This service will run three times a week. Between the Bohemian capital and Warsaw there is a daily passenger service; and Rome is now on the Continental air trade-routes.

It would not be quite true to say that there is extensive carriage of cargo and commodities over these lines, but the mere fact that Queen Alexandra was able to send her sister in Copenhagen fresh vegetables and fruits for the table the other day hints at the possibilities and practicabilities of the airplane. Shortly after the signing of the armistice, a large department store in London inaugurated an aerial delivery service to Brussels. Mail orders were filled on the day of receipt. This occurred at a time when transportation facilities were completely tied up; deliveries were being delayed weeks in transit. In accordance with the effectiveness of service the salesman who made delivery in Brussels usually came back to London with additional orders.

Why is the United States, the most progressive of nations, so backward in aerial transportation? It seems strange that we maintain such a conservative attitude toward an invention of our own, one which promises limitless possibilities and such huge financial returns?

The Air Mail Service has proved that it can not only expedite our mail deliveries, but that it is a sound and profitable business investment. "The mail must fly" has been the slogan, and the mail has flown every day except Sunday between Washington and New York City and daily to New York City, Cleveland and Chicago, defying all sorts of weather conditions for over two years.

Commercial aviation is here, but it will not develop by itself. The United States must shake herself out of her colossal inertia. She must back up the project financially. Men of brains and genius are making the development of aviation their life-work. Popular prejudice and skepticism must be overcome. The airplane is a reliable means of transportation; and not only a reliable but a safe method of travel.

In closing, I wish to cite a few statistics that were published recently regarding European air travel. Between Feb. 5 and Aug. 31, 1920, the aerial passenger and mail services of Germany have made 5378 flights, negotiating over 533,000 miles with the loss of one pilot. The public air transport over French territory, and operated by French companies abroad, flew over 700,400 miles in the past year, with but one fatality. From May, 1919, to Dec. 1, 1920, the London-Paris and London-Brussels services have made several trips daily and have had only one passenger killed. From May 17 to Sept. 30, 1920, the London-Amsterdam mail and passenger services flew 93,200 miles with no accidents of any kind. The aerial passenger, mail and express services of England have, from May, 1919, to July, 1920, a period of 15 months, flown over 1,500,000 miles or 60 times the distance around the world.

WORLD'S PRODUCTION OF PETROLEUM

THE estimated world's production of petroleum in 1920 is 688,474,251 bbl. against 554,505,048 bbl. in 1919, according to figures assembled by the American Petroleum Institute. This represents a gain of 133,969,203 bbl. or 24.2 per cent.

Of the total production in 1920 the United States supplied 443,402,000 bbl. or 64.4 per cent. Mexico supplied 159,800,000 bbl. or 23.2 per cent of the world's output. By far the greater gains were made by the United States and Mexico. United States production increased from 377,719,000 bbl. in 1919 to 443,402,000 bbl. in 1920, a gain of 65,683,000 bbl. or 17.4 per cent. Mexico increased from 87,072,954 bbl. to 159,800,000 bbl., a gain of 72,727,046 bbl. or 83.5 per cent in spite of unsettled conditions.

A comparison of the statistics for 1920 and 1919 reveals the effect of the unsettled conditions resulting from the world war. Assuming that the 1920 figures are approximately correct, it will be noticed that the production in Russia declined over 4,000,000 bbl. Another noteworthy change is the shifting of the production in the Alsatian field from Germany in 1919 to France in 1920.

The estimated production for 1919 and 1920 by countries is given in the accompanying table, the figures being in barrels in all cases.

WORLD'S PETROLEUM PRODUCTION

	1920	1919
United States	443,402,000	377,719,000
Mexico	159,800,000	87,072,954
Russia[1]	30,000,000	34,284,000
Dutch East Indies	16,000,000	15,780,000
India	8,500,000	8,453,800
Roumania	7,406,318	6,517,748
Persia	6,604,734	6,289,812
Galicia	6,000,000	6,255,000
Peru	2,790,000	2,561,000
Japan and Formosa	2,213,083	2,120,500
Trinidad	1,628,637	2,780,000
Argentina	1,366,926	1,504,300
Egypt	1,089,213	1,662,184
France[2]	700,000	.....
Venezuela	500,000	321,396
Canada	220,000	220,100
Germany[2]	215,340	925,000
Italy	38,000	38,254
Total	688,474,251	554,505,048

[1]No exact information available.
[2]The Alsacian field's production appears under Germany in 1919 and under France in 1920.

Developments in Transmission[1]

By Capt. S. Bramley-Moore *Illustrated with* Drawings

In this paper it is my intention to discuss certain developments in clutch and gearbox design with a view to reducing the cost of upkeep. It has been said that more money is spent on the repair and maintenance of the average transmission system than on the engine itself. This may or may not be true, but it is certain that modern high-power engines, capable of quick acceleration, can easily overload all parts of the transmission gear. Probably, however, more trouble is caused by difficulty in gear-changing and careless clutch manipulation, the latter providing a steady source of revenue to tire manufacturers.

If the ingenuity expended on modern disc and plate clutches had been bestowed on cone clutches, the latter would have proved so cheap, simple and satisfactory that the former would have been regarded in the nature of an extravagant luxury. The development of the cone clutch has been sadly neglected, while other types have been "nursed" into public favor.

Clutches drive by friction, and surely there can be no more effective form of friction than the tapered wedge action of two conical surfaces. The disc clutch is, moreover, theoretically incorrect, due to the extra spring pressure required to drive by friction between flat plates, as compared with the wedge-shaped cone, and the uneven wear due to different rubbing speeds, owing to the fact that at every different radius of the plate there is a different velocity. When clutch springs are evenly spaced around the face of the disc it is probably impossible to guarantee that all these shall exert the same pressure, and any difference in pressure will cause uneven loading and uneven wear, the portion adjacent to the strongest spring attempting to carry more than its proper share of the drive. In spite of these inherent drawbacks the disc clutch has been so carefully developed that certain designs give very satisfactory service.

The ordinary plate clutch runs in a bath of oil, and its successful action depends upon efficient lubrication. If the oil gets too thick or congeals it will prevent the driving and driven plates from separating properly when the clutch is disengaged. This will cause the car to "creep" in traffic although the clutch pedal may be fully depressed, and it will also greatly increase the difficulty of gear-changing. When starting from rest, the teeth of the first-speed gears are likely to grate and rub together as they are brought into engagement, owing to the continued rotation of the driven portion of the clutch. This difficulty is worse in cold weather, especially if the car has been standing for a few days. In the case of a well-known American car, in which the plate clutch has to be disengaged before starting up the engine, the danger is so great that it is frequently necessary, during the winter season, to jack up the rear axle before "winding up." Thin oil, on the other hand, is likely to make the clutch too fierce.

The Cone Clutch

The ordinary leather-faced cone clutch, the pioneer type, is simple, cheap and reliable, but frequently fails to provide for a sufficiently gradual engagement when starting up from rest. This is due to the fundamental absurdity that the moment the clutch surfaces come into contact, the full pressure of the clutch spring comes into immediate operation. When the driver begins to release his clutch pedal, the clutch surfaces have not begun to make contact, and then, all too suddenly, the cones engage. At this critical point the driver very often lacks sufficient control, or the requisite delicate touch, to prevent a sudden and jerky picking up of the load.

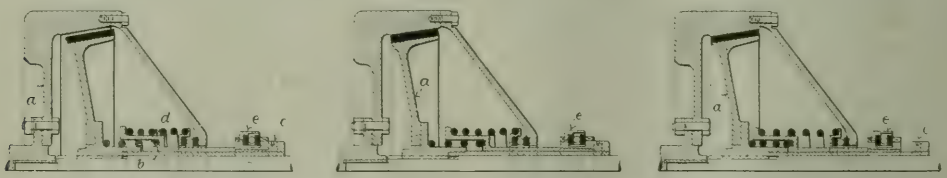


Fig. 1—Three Positions, Disengaged, Partly Engaged and Fully Engaged, of a Double-Spring Clutch

Fig. 1 shows three positions of a double-spring clutch designed to overcome this most objectionable characteristic of the ordinary type. The clutch cone *a* is operated by the sleeve *b* controlled by the collar *c*. The inner and outer clutch springs are separated by the sleeve *d* controlled by the ball thrust collar *e*, operated by a clutch pedal in the usual way. The inner spring acts directly on the clutch cone *a*, while the outer spring acts on the sleeve *d*.

The view at the left shows the collar *e* withdrawn, thereby disengaging the cone *a* through the medium of in collar *c*. In the middle view the collar *e* is shown partially released, thus allowing the cone *a* to engage with the flywheel. The inner spring is, however, as yet exerting no pressure on the cone so that the latter is only able to transmit a small torque, not sufficient to cause any jerk or jar. If, from this position, the clutch pedal be gradually released, the pressure of the inner spring will gradually increase, thus permitting the clutch to pick up its load in a smooth and uniform manner as shown at the right. Here the collar *e* is entirely released and the clutch fully engaged. Note that the inner spring is now only 2 in. long, thus exerting its full pressure, as against 2½ in. in length in the previous view. Also note the gap of ½ in. between the collars *c* and *c*, while these were previously in contact. This large travel is shown only

[1] From a paper presented at a recent meeting of the Institution of Automobile Engineers.

for illustrative purposes, and is not required in actual practice.

Fig. 2 shows an additional device fitted to this type of clutch with a view to eliminating the "human element." In this case the sleeve *f* is secured by a pin *g* to a boss forming part of the plunger *h*. When the cone *i* is withdrawn by its operating collar *j* it simultaneously moves the sleeve *f* and plunger *h*, thus allowing oil to be sucked through the passage *k* and ball valve *l* into the chamber *m*, the engine being provided with a hollow crankshaft and forced-feed lubrication. If the clutch pedal be suddenly released, the cone *i* will re-engage with the flywheel, but the sleeve *f* will be left behind owing to the dashpot *m*. This position of *f* is illustrated in the lower right corner and in this position the inner spring is extended so that it is exerting little or no pressure on the cone *i*.

As, however, the oil from the chamber *m* is gradually forced back into the hollow crankshaft, through a narrow groove that is always open, by the pressure of the outer clutch spring, so the pressure of the inner spring, acting directly on the cone *i*, will gradually increase, thus allowing the clutch to pick up its load gradually without any possibility of jerk or jar.

It is now proposed to show how the drawbacks of the ordinary cone clutch can be overcome by a double cone and single spring, in place of the double spring and single cone already described. In the early days of motoring, when the cone clutch was almost universally adopted, many experiments were made to decide the most suitable angle of cone to give the best all-round results. The problem was how to employ a light spring without unduly increasing the diameter of the clutch. The larger the angle, the less the possibility of a fierce clutch, but the greater the difficulty in transmitting the drive, notwithstanding the use of a powerful spring. The smaller the angle, the lighter the spring, but great care was necessary in engaging the clutch; otherwise the engine would frequently be stopped, or the car jerked into motion, owing to the sudden taking up of the load.

At the left of Fig. 3 is shown a double-cone clutch combining the good points of both these two extremes in the disengaged position. This clutch comprises two driving cones, an inner and an outer, the former having a large angle, and the latter a small one. On first releasing the clutch pedal only the inner cone, with the large angle, comes into operation, as shown in the center of the illustration, and, owing to the use of a light clutch spring, this part of the clutch is able to transmit only a small portion of the power, not sufficient to cause any shock, no matter how suddenly applied. In other words, the inner cone will be compelled to slip, and this slip will allow the clutch to pick up its load gradually. Once the car is in motion the clutch pedal is fully released, thus allowing the outer cone, with the small angle, to pick up the drive, as shown at the right, and this without any risk of further slip, and with a minimum of both spring pressure and clutch diameter, which could not possibly be obtained with the orthodox pattern of single cone clutch.

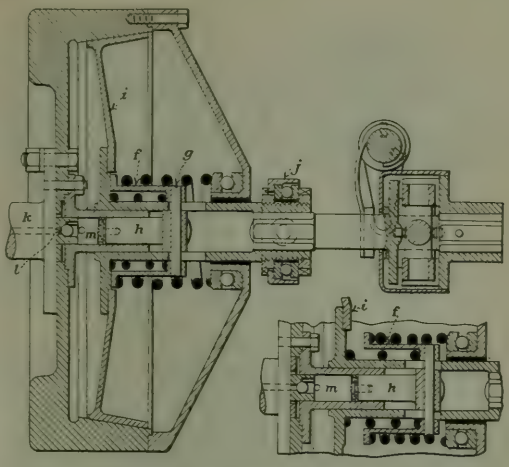


FIG. 2—CLUTCH WITH AUTOMATIC ENGAGING DEVICE

In Fig. 3 the cones *n* and *o* are the driving members, both rotating at the same speed, and *p* is the driven member. In the view at the left the clutch is entirely disengaged, all three cones being out of contact with each other. In this position the clutch pedal is, of course, fully depressed. The middle view shows the position of the clutch for starting the car from rest. Only the cone *n* has engaged the driven member *p*, and this portion of the clutch is designed so that it does not possess sufficient "grip" to jerk the car, although it is able to set the vehicle in motion. This characteristic is due to the large cone angle and light clutch spring.

At the right the clutch is shown fully engaged, the driven member *p* being sandwiched between the two driving cones *n* and *o*. In this position the clutch is able to transmit the full power of the engine. There is no possibility of slip because of the powerful grip of the outer cone *o* due to the small cone angle.

When the clutch pedal is first released, the cone *n* engages with the cone *s* before the latter engages with the cone *o*. This is due to the fact that the cones *n* and *p* travel at a different rate. The driven member *p* is operated by the "slow moving" link *q*, which is pivoted half-way up the "fast moving" operating lever *r*, so that the end of *r* will move approximately twice as far as the link *q*, because the radius of the former is

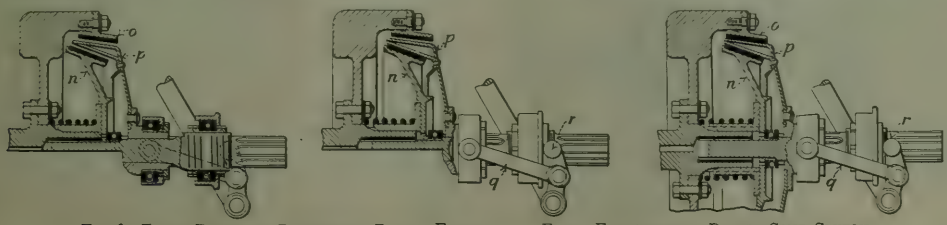


FIG. 3—THREE POSITIONS, DISENGAGED, PARTLY ENGAGED AND FULLY ENGAGED, OF A DOUBLE-CONE CLUTCH

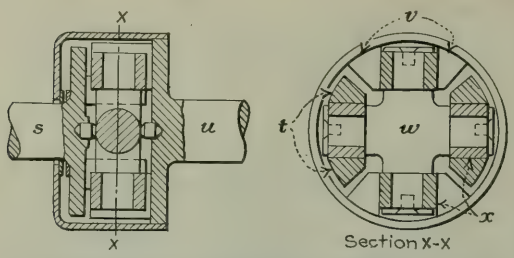


FIG. 4—A COUPLING WHICH IS A UNIVERSAL-JOINT AND IS CAPABLE OF MOVEMENT IN AN ANGULAR DIRECTION AS WELL AS CONVEYING MOTION BETWEEN TWO SHAFTS WHOSE AXES ARE PARALLEL BUT NOT IN THE SAME STRAIGHT LINE

twice that of the latter. Th terms "slow moving" and "fast moving" are, of course, used only in a relative sense.

UNIVERSAL-JOINT AND GEARBOX DESIGN

It may surprise some to hear that the "universal-joint" in common use is not universal, and in all probability there is no automobile on the road provided with a coupling which gives a universal movement. The ordinary pivoted form of coupling permits of movement in an angular direction only, and is known as a Hooke's joint. One such joint is unable to convey motion between two parallel axes not in the same straight line, in which case two joints must be used. For this reason two joints are generally fitted between the engine and gearbox of a motor vehicle when these two units are independent of each other. The Oldham coupling, on the other hand, is designed to convey motion between any two shafts of which the axes are parallel but not in the same straight line, but is not adapted to accommodate movement in an angular direction.

Fig. 4 shows a coupling which is a universal-joint in the true sense of the word, as it combines the movements of the two types of couplings already referred to. The driving shaft *s* carries jaws *t* and the driven shaft *u* carries jaws *v*. Motion is communicated from one to the other by the cross-piece *w* which is fitted with driving blocks *x*. If the blocks were rigidly fixed to the jaws *t* and *v* respectively, an ordinary type of Hooke universal joint would result, providing angular movement only. If, on the other hand, the blocks were fixed to the arms of the cross-piece *w*, so as to prevent any rotary movement, the cross-piece and blocks would be left with a sliding motion only, this movement corresponding to that of an ordinary Oldham coupling.

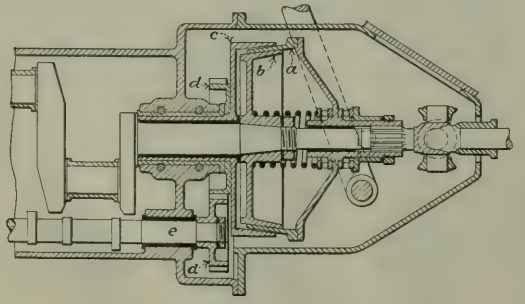


FIG. 5—A SIMPLE TYPE OF TWO-SPEED GEAR

But as the arms of the cross-piece *w* are free to pivot about the driving blocks *x*, and as the blocks are also free to slide in the jaws *t* or *v*, it will be seen that this design combines the characteristics of the Hooke and Oldham joints in one coupling. It therefore follows that one such coupling, placed between the engine and the gearbox of a motor vehicle, will meet all the requirements of both angular and parallel displacement.

There is no need to waste time in introducing the subject of gearbox design; it is an acknowledged fact that the ordinary clash type of gearbox is unmechanical and unsatisfactory. Experts pretend that there is no difficulty in gear-changing, but owner-drivers know otherwise. During 5 years' Army experience I have come in contact with thousands of drivers, being at one time responsible for the technical training of nearly 2000 men per week, and I can state definitely that the ordinary man regards the conventional gearbox as an extraordinary abomination.

Fig. 5 shows a simple type of two-speed gear designed to eliminate unnecessary gear wheels. The driven clutch cone *a* is provided with two faces, an inner and an outer. The inner face is able to engage with the high-speed cone *b*, which is keyed to the crankshaft of the engine. The outer face is able to engage with the low-speed cone *c*, which is mounted loosely on the rear end of the crankshaft, being driven from the camshaft by the low-speed gears *d*.

Under ordinary conditions the clutch spring keeps the cone *a* in engagement with *b* thereby providing the high-speed direct drive. For the low speed the clutch pedal must be depressed, thereby causing the cone *a* to engage with the low-speed cone *c*. In this position the drive will pass through the two-to-one timing-gears at the front end of the engine, which are not shown, and then along the camshaft and through the low-speed gears *d* to the low-speed cone *c*. The camshaft *e* is designed to carry this extra load, or alternatively the timing-gears can be placed alongside the gears *d*. With the arrangement shown the flywheel is located at the front end of the engine, and the reverse-speed mechanism forms part of the differential gear in the rear axle. The design of this gear is both cheap and simple, the only extra parts required being two gear wheels and an outer cone.

Figs. 6 and 7 illustrate the application of double helical gears to a four-speed gearbox. Double helical gears, unlike the ordinary straight spur type, give continuous rolling contact on the pitch line. They can also withstand a greater stress, for there is, at any instant, a stress on one portion of the tooth only, the other portions being out of engagement, while on a straight spur the stress is continuous along the whole length of the tooth. They also possess the great advantage, for automobile work, of silent running, the general design of the gear enabling a finer pitch to be employed than would be possible with a corresponding straight spur. A double helical generator has recently been made by David Brown & Sons which is adapted to produce automobile gears with the teeth cut from the solid in one continuous piece.

In the ordinary way, double helical gears are not adapted to an automobile four-speed gearbox, owing to the difficulty of restricting the length of the box to reasonable dimensions. Everybody knows that the ordinary four-speed gearbox possesses a minimum number of eight gear wheels, excluding the reverse-speed gear wheels. A unique characteristic of the present design, however, is the fact that only six gear wheels are required to provide four forward speeds, in place of the

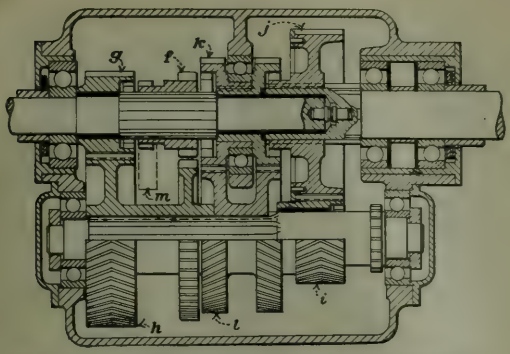


FIG. 6—DOUBLE HELICAL GEARBOX SHOWING THE ARRANGEMENT OF THE GEARS FOR FIRST AND SECOND SPEEDS

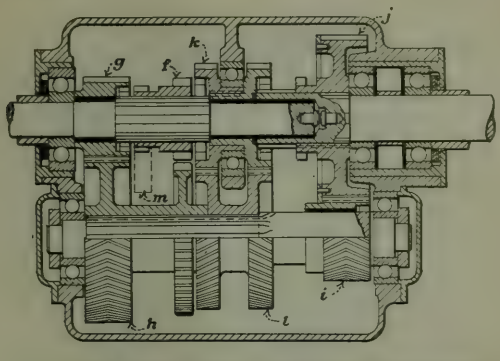


FIG. 7—DOUBLE HELICAL GEARBOX SHOWING THE ARRANGEMENT OF THE GEARS FOR THIRD AND FOURTH SPEEDS

usual eight. The four speeds are obtained in the following manner:

With the position of the gears as shown in Fig. 6, move *f* to the left for the first speed and to the right for the second speed. The drive will then pass through *g h*—*i j* and *k l*—*i j* respectively.

With the position of the gears as shown in Fig. 7, move *f* to the left for the third speed and to the right for the fourth speed direct drive. The drive will then pass through *g h*—*k l* and *f k j* respectively.

A reverse speed is obtained by moving the gear pinion *m* to the right when the gears are in the position shown in Fig. 6.

The chief characteristic of this gear, four speeds forward with only six wheels, is obtained by loosely mounting the gear wheel *k* at the junction of the driving and driven shafts, so that it can be locked to the driving shaft, or to the driven shaft, or to both together, thus enabling it to transmit power to, or receive power from the countershaft in addition to transmitting the top speed direct drive. Gear-changing is also greatly facilitated, as it is much easier to engage two sets of internal teeth, of which the shafts are rotating in the same direction, than to engage two spur gears, as in the ordinary type of box, of which the shafts are rotating in opposite directions.

The right and left-hand helicals of gear wheels *k* and *l* are shown separated by a gap, to incorporate the ball bearing supporting *k*. These are, of course, two gear wheels, not four, as both right and left-hand helicals are generated simultaneously, and the gears could just as easily be joined together, like *h* or *i*, if so required.

Fig. 8 illustrates a new type of four-speed gearbox, and the four views in Fig. 9 show the manner in which the various speeds are obtained. The characteristic feature of this box is a double-acting cone friction clutch in conjunction with six gear wheels arranged in the special manner already described so as to provide for a range of four speeds. The double clutch provides for a change of speed from first to second or from third to fourth or vice versa without touching the gearbox change-speed lever, thereby greatly facilitating the operation of changing speed.

The driving member of the clutch, *n*, is provided with two faces, an inner and an outer, so that it is able to engage with either of the driven cones *o* or *p*. The cone *o* is keyed to a sleeve carrying the gear pinion *q*, and the cone *p* is mounted on a castellated shaft *r* to which the gear pinion *s* is also keyed. The pinions *q* and *s* engage with two gear wheels *t* and *u* mounted on the countershaft; the latter also carries a gear pinion *v* engaging with a gear wheel *w* mounted on the castellated driven sleeve *x*.

For the first and second speeds the gear wheel *w* is engaged with the gear pinion *v*. For the third and fourth speeds the wheel *w* is moved over to the left, so that it engages, through dog clutches, with the gear pinion *s*, which is thus locked to the driven sleeve *x*. Thus the change-speed lever controlling the gear *w* has only to be moved when changing from second to third speed or vice versa.

In shifting the gears to get the first speed at the upper left corner of Fig. 9 the clutch pedal is pushed forward so that the cone *n* drives the cone *o*. Then *q* drives *t* and *v* drives *w*. To obtain the second speed in the lower left corner the clutch is released so that the clutch spring forces the cones *n* and *p* into driving engagement. Then *s* drives *u* and *v* drives *w*. In the third speed at the upper right corner the gear *w* has been moved over so as to lock the gear *s* to the driven sleeve *x* (see Fig. 8), and the clutch pedal is pushed forward so that the cone *n* drives the cone *o*. Then *q* drives *t* and *u* drives *s*. To obtain the fourth speed in the lower right corner the clutch pedal is released so that the clutch spring forces the cones *n* and *p* into driving engagement. Then *s* drives *w*, thus giving a direct through drive.

For a reverse speed the gear *w* is left in a neutral position and the pinions *y* and *z* (see Fig. 8) are moved

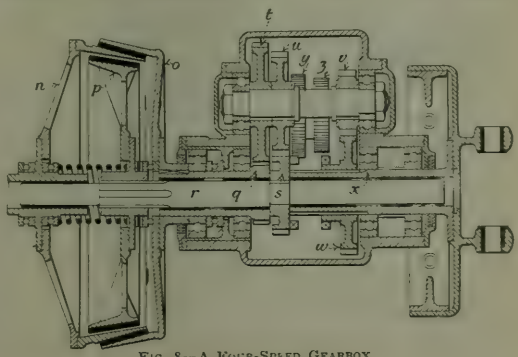


FIG 8—A FOUR-SPEED GEARBOX

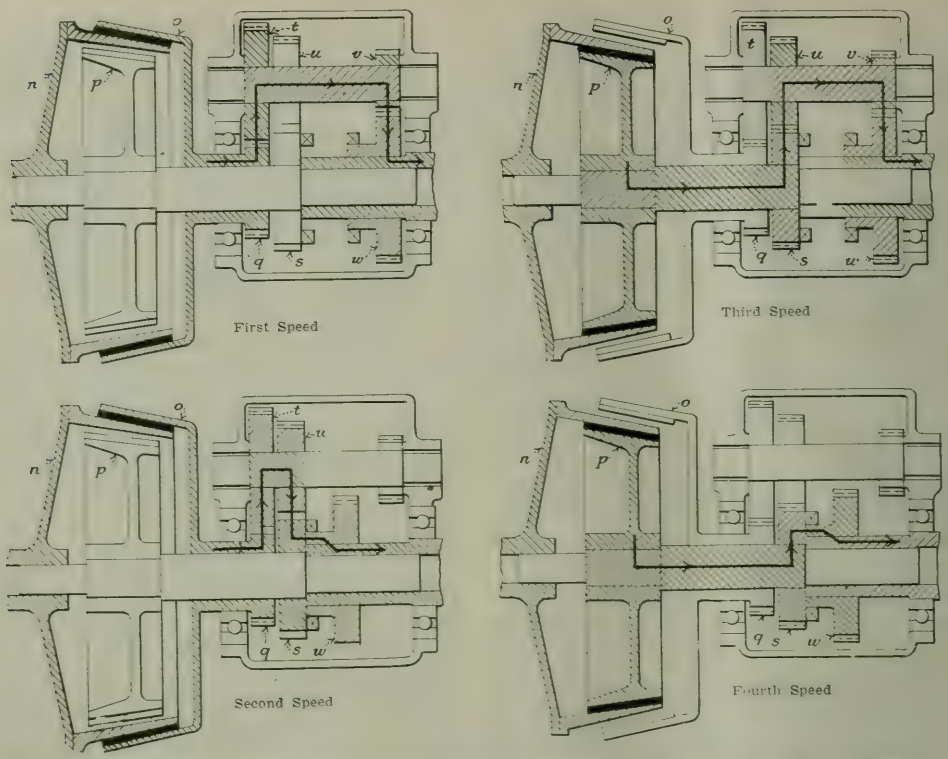


FIG. 9—DIAGRAM OF A FOUR-SPEED GEARBOX SHOWING THE ARRANGEMENT OF THE GEARS TO SECURE VARIOUS SPEEDS

into mesh with the two gear wheels *w* and *v* respectively. In this position if the clutch pedal be pushed forward it will give a low reverse speed for traffic work, and if released will give a higher reverse speed for use on a country road, having, for example, overshot the desired turn by perhaps 100 yd. The clutch is, of course, in neutral when the clutch pedal is in any intermediate position.

The gate, as far as the forward speeds are concerned, is merely a single slot, one end of which is marked

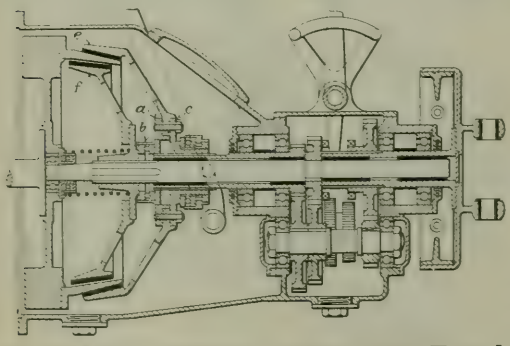


FIG. 10—A UNIT CONSTRUCTION FOUR-SPEED GEARBOX WHICH IS CAPABLE OF BEING BOLTED TO THE REAR END OF THE CRANKCASE

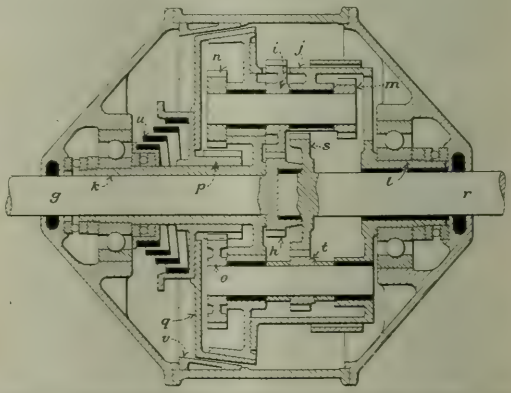


FIG. 11—EPICYCLIC GEARBOX PROVIDING FOUR FORWARD SPEEDS AND A REVERSE SPEED

"slow" and the other end "fast." The "slow" position provides for first and second speeds and the "fast" position for third and fourth speeds. A ratchet device, capable of instant release, automatically holds the clutch pedal forward when on first and third speeds. For a momentary change, however, as when starting from rest, or when dropping into third speed for a few sec-

onds for traffic congestion, this ratchet would not be brought into operation.

It will be observed that the clutch angles of the inner and outer cones are different. As the inner cone is never used for starting the car from rest, a small angle can be used, although naturally the angle must not be decreased below that point at which the clutch might "stick," rendering it hard to disengage. A small angle enables a weak clutch-spring to be employed, and this reduces the pressure required to hold the clutch pedal in a neutral position. The outer cone is used for starting the vehicle from rest, and a corresponding angle may be chosen, thus facilitating easy clutch engagement. The outer cone may be engaged without transmitting any drive, and then, as the pressure on the clutch pedal is gradually increased, the clutch will gradually pick up its load without jerk or jar. Clutch adjustment is rarely necessary, owing to the fact that two clutch faces take the drive, one on the first and third speeds and the other on the second and fourth speeds, thus distributing the wear and prolonging the life of the clutch lining. In Fig. 8 suitable packing washers are provided, however, which regulate the distance between the two clutch faces *o* and *p* should adjustment ever become necessary.

Fig. 10 shows a somewhat different design adapted to bolt up to the rear end of the engine crankcase. In this case the gate and change-speed lever are carried by the lid of the gearbox, and self-locking clutch adjustment is provided as follows: The discs *a* and *b* are screwed together, and can have no relative movement when the bolts *c* are in position owing to the castellations of the sleeve *d*, the disc *b* being castellated to correspond. When, however, the bolts *c* are withdrawn, the cone *e* can be rotated about *b*, thus drawing the driving surfaces of *e* and *f* more closely together to compensate for wear. It may be remarked that this gearbox is 35 per cent shorter than the ordinary type, and requires only two selector rods in place of the usual three.

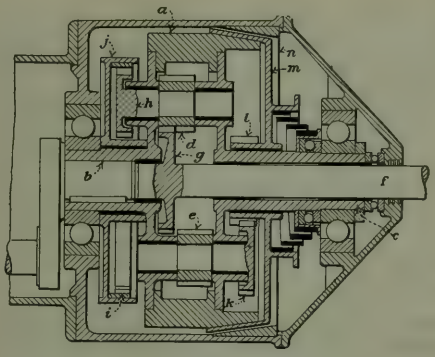


FIG. 13—A UNIT CONSTRUCTION EPICYCLIC GEARBOX WHICH CAN BE BOLTED TO THE REAR END OF THE ENGINE

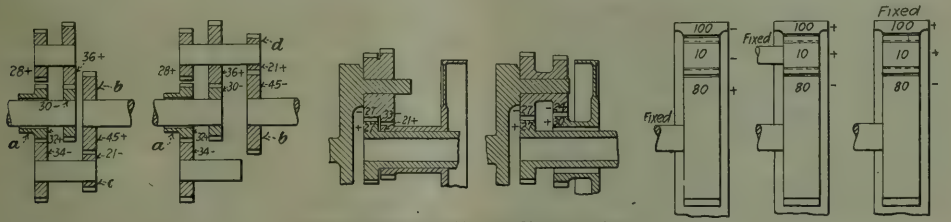


FIG. 12—DIAGRAM OF VARIOUS EPICYCLIC GEARS

EPICYCLIC GEARS

The advantages of epicyclic gears are too well known to need emphasizing in this paper. In the past, however, they have suffered, when designed to transmit three or four speeds, from two serious defects, weakness of construction and a general complication of parts. It is hoped that Figs. 11, 13 and 14 will open up a new point of view, and the more thoroughly these designs are discussed, the more helpful it will be for the future development of this type of gear.

In Fig. 11 the driving shaft *g* carries the sun wheel *h* meshing with the planetary gear *i* mounted in bearings carried by the cage *j*. This cage is supported by the sleeves *k* and *l*, the parts *j* and *k* being rigidly bolted together. Thus the cage *j* is of rigid construction, being carried by two large ball bearings, one at each end of the gearbox casing as shown. The spindle of the planetary gear *i* carries two additional planetary gears, *m* and *n*, the latter meshing with the planetary gear *o* which engages with the sun-wheel *p* controlled by the clutch cone *q*. For the sake of simplicity, the drawing shows the planetary gears *n* and *o* separated from each other, although it must be understood that the spindles are actually arranged so that these two gears are in continual engagement with each other.

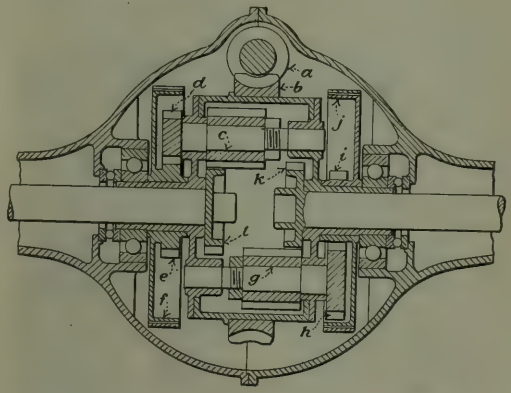


FIG. 14—AN EPICYCLIC GEAR DESIGNED TO FORM PART OF A REAR-AXLE SPUR-TYPE DIFFERENTIAL

The driven shaft r carries the sun-wheel s shown in mesh with the planetary gear t, but the shaft r is arranged to slide, being controlled by external operating mechanism, so that in its other extreme position the sun-wheel s can engage with the planetary gear m.

The clutch cone q is provided with two faces, an inner and an outer, and for the top speed the clutch spring u forces the inner face into contact with the cage j, thus causing the cage, planetary gears and sun-wheels to rotate as one solid mass, thereby providing a direct through drive. This position is illustrated in Fig. 11.

If, however, the clutch pedal controlling q be fully depressed, it will cause the outer cone to engage with the stationary ring v, thereby bringing the sun-wheel p to rest. The drive will then pass from g to i, n to o and t to s. If the pedal controlling the brake band which encircles the cage j be depressed, the action will automatically, by means of a cam, throw the clutch cone q into an intermediate or neutral position, simultaneously bringing the cage j to rest. The drive will still pass through the same gear wheels as before, only in this case the cage j will be stationary and the sun-wheel v idly rotating, thus bringing a different gear ratio into action.

The shaft r carrying the sun-wheel s should now be moved so as to bring s into engagement with the planetary gear m. In this new position two more speeds can be obtained, one by bringing the clutch cone q to rest against the stationary ring v, and the other by the operation of the brake band on the cage j.

The ordinary type of epicyclic gear, if designed to provide for five different speeds, becomes both clumsy and complicated. The design in Fig. 11 is rigid and compact, and, as shown, gives four speeds forward and one reverse.

It may be objected that the sliding movement of the sun-wheel s eliminates that simplicity of operation which is one of the great features of the epicylic gear. This objection is not, however, very serious owing to the fact that the fourth, third and second speeds are all obtained with s in mesh with t as shown in Fig. 11. It is quite easy, except on hills, to start up on second speed, so that s need never be moved except in case of an emergency or for reversing. It is believed that this design is more or less unique, and it is put forward, not so much as a solution of the problem, but rather as an incentive to stimulate designers to investigate new possibilities hitherto unexplored.

It is not everyone who is familiar with the process by which epicyclic gear ratios are calculated. Those who rely on cut-and-dried formulas will not find the gear ratio of Fig. 11 easy to solve, as this design is not to be found in the usual reference or textbook. But by the application of first principles, which is better than a bookful of formulas, the value of the ratios can be quickly ascertained. Thus to find the gear ratio when the sun-wheel a is held fast, with the driven gear b in mesh with the planetary gear c, as shown in the diagram at the extreme left of Fig. 12. To facilitate calculation imagine the cage to be fixed and assume the fixed member, a, to make one revolution in a positive direction. Insert the plus and minus signs as shown, whence it will be seen that h (see Fig. 11) is going in a negative and b or s in Fig. 11 in a positive direction. Now work out, by simple proportion, the relative speeds of these two gears, taking care, in each case, to subtract 1 from the answer so as to eliminate the fictitious plus 1 revolution which the fixed member a was assumed to make. The figures in the diagram indicate the number of teeth in the gears. Then the speed of the driver equals

$$-\left(\frac{32}{34}\times\frac{34}{28}\times\frac{36}{30}\right)-1=-2.37 \text{ revolutions}$$

The speed of the driven gear equals

$$+\left(\frac{32}{34}\times\frac{21}{45}\right)-1=-2.56 \text{ revolutions}$$

The gear ratio is the quotient of the speed of the driver divided by the speed of the driven gear or $-2.37 \div -0.56 = +4.23$. The final answer, being positive, indicates that the gear ratio is 4.23 to 1 in a forward direction.

To find the gear ratio when the sun-wheel a is held fast, with the driven gear b in mesh with the planetary gear d, as shown in the second diagram of Fig. 12. Insert plus and minus signs on the assumption that the fixed member a makes plus one revolution with the cage stationary. Then the speed of the driver equals

$$-\left(\frac{32}{34}\times\frac{34}{28}\times\frac{36}{30}\right)-1=-2.37 \text{ revolutions}$$

The speed of the driven gear equals

$$-\left(\frac{32}{34}\times\frac{34}{28}\times\frac{21}{45}\right)-1=-1.53 \text{ revolutions}$$

The gear ratio determined as in the previous case is $-2.37 \div -1.53 = +1.55$.

Two more speeds can be obtained with a stationary cage, one with b in mesh with d, and the other with b in mesh with a. Obviously the former will be a forward speed, and the latter, owing to the introduction of an intermediate gear, is bound to be in the reverse direction, the gear ratios being as follows:

$$\text{Forward speed} = +\left(\frac{36}{30}\times\frac{45}{21}\right)=+2.57 \ (d \text{ driving } b)$$

$$\text{Reverse speed} = -\left(\frac{36}{30}\times\frac{34}{28}\times\frac{45}{21}\right)=-3.12 \ (a \text{ driving } b).$$

The three forward speeds which can be obtained with b in constant mesh with d are, therefore, 2.57, 1.55 and 1.0 or direct, equivalent to 15.5, 26.0 and 40 m.p.h. For the reverse speed and the emergency forward speed, b has to be moved into mesh with a.

To calculate any epicyclic gear ratio, without resorting to formulas, which are sometimes unobtainable, the following system, common to all types, can be employed:

(1) Assume the planetary arm to remain stationary
(2) Assume the fixed member to make one revolution
(3) Ascertain directions by inserting plus and minus signs
(4) Calculate, from (2), the revolutions of the driver and subtract one
(5) Calculate, from (2), the revolutions of the driven gear and subtract one
(6) Divide (4) by (5). The answer gives the gear ratio

A simple but interesting example is that of the Ford epicyclic gear. With a dismantled gearbox on the workshop table, I have asked competent mechanics to explain the working of the gear. Pitying my ignorance, they have cheerfully undertaken the task, but after 10 min. of unnecessary preamble they often scratch their heads, being quite unable to explain why the car should go backward on the reverse speed. Neglecting formulas, and working from first principles, the proposition is, however, extremely simple. The third diagram in Fig. 12 shows the train of gears used to obtain the low forward speed, and the next one shows the train used for the reverse speed.

In both cases insert plus and minus signs, as shown,

imagine the planetary arm fixed, in this case it is really the driver, and assume the fixed member to make one revolution in a positive direction.

Then, in the third diagram the revolutions of the driver equal — 1 and the revolutions of the driven gear equal

$$+\left(\frac{21}{33}\times\frac{27}{27}\right)-1=-0.36.$$

The gear ratio is $-1\div-0.36=+2.76$. In the next diagram the revolutions of the driver equal — 1 and the revolutions of the driven gear equal

$$+\left(\frac{30}{24}\times\frac{27}{27}\right)-1=+0.25.$$

The gear ratio is $-1\div+0.25=-4.0$, the backward direction being indicated by the minus sign.

From an examination of the above it will be obvious that if both sun gear wheels have an equal number of teeth, the gear ratio will be zero; in other words, if the brake-drum were held fast the driven shaft would remain stationary because the revolutions of the driver equal — 1 and the revolutions of the driven gear equal

$$+\left(\frac{27}{27}\times\frac{27}{27}\right)-1=0$$

It is equally important to note that, in the above case, when the fixed sun is smaller than the driven sun, the resulting speed will be forward, but if the fixed sun be the greater, the driven shaft will rotate backward.

The ratios of an epicyclic train with an internal gear can also be instantly calculated. Three gear wheels can provide six different combinations, and three different diagrams are necessary in order that the plus and minus signs may be inserted. Proceeding exactly as before, the gear ratios of the last three diagrams of Fig. 12 can be quickly ascertained.

In the first of the combinations the sun wheel is fixed while the planetary aim drives the internal gear. The revolutions of the driver equal — 1; the revolutions of the driven gear equal $-(80\div100)-1$ or — 1.8 and the gear ratio is + 0.56. In the next combination which also refers to the same diagram the sun wheel is fixed as before but the planetary arm is driven by the internal gear. The revolutions of the driver equal $-(80\div100)$ — 1 or — 1.8; the revolutions of the driven gear equal — 1 and the gear ratio is + 1.8.

In the first combination for the next diagram the planetary arm is fixed and the sun wheel drives the internal gear. As the planetary arm is fixed epicyclic motion is eliminated and the gear ratio is therefore $-(100\div80)$ or — 1.25. In the next combination the planetary arm is fixed and the sun wheel is driven by the internal gear. Epicyclic motion is again eliminated and the gear ratio is $-(80\div100)$ or — 0.8.

In the next combination which refers to the diagram at the extreme right, the internal gear is fixed and the planetary arm drives the sun wheel. The revolutions of the driver equal — 1; the revolutions of the driven gear equal $-(100\div80)\ 1=-2.25$ and the gear ratio is + 0.45. In the sixth and last combination the internal gear is again fixed while the sun wheel drives the planetary arm. The revolutions of the driver equal $-(100\div80)-1$ or — 2.25; the revolutions of the driven gear equal — 1 and the gear ratio is + 2.25.

Fig. 13 illustrates an epicyclic gear adapted to bolt up to the rear end of the engine casing. The flywheel *a* is bolted between the two sleeves *b* and *c*, carried by two large ball bearings as shown. This type of gear is quite different from that shown in Fig. 11, inasmuch as in this case the planetary gears are carried by a continuously rotating cage, *b*, which is keyed to the crankshaft of the engine.

To simplify the drawing, the two planetary gears *d* and *e* are shown separated from each other, although their spindles are actually mounted so as to enable the two gears to engage with each other over approximately half their face width, similar to the arrangement of an ordinary spur-type differential gear. The driven shaft *f* is controlled by operating mechanism so that the sun-wheel *g* can be brought into mesh with the planetary gear *d* alone, or, in a midway position, with planetary gears *d* and *e* simultaneously, or with the planetary gear *e* alone.

The spindle of the planetary gear *d* carries another planetary gear *h* meshing with the internal gear wheel *i* controlled by the brake-drum *j*. The spindle of *e* carries another planetary gear *k* in constant mesh with the sun-wheel *e* which can be brought to rest by the clutch cone *m*, which is capable of engaging with the fixed ring *n*.

Only seven gear wheels are shown, although additional gears should be embodied for the sake of balance and even load distribution and with these few parts the gear is capable of providing four speeds forward and one reverse. Having already explained Fig. 11 in detail, the action of the present design may be briefly summarized as follows:

> For the direct drive release the clutch pedal so as to allow the clutch cone *m* to engage with the flywheel *a*, thereby causing the planetary gears and sun-wheels to rotate as one solid mass. Still leaving the sun-wheel *g* in mesh with the planetary gear *d*, two additional speeds can be obtained, one by engaging the clutch cone *m* against the stationary ring *n*, and another by holding the brake-drum *j* with the clutch cone *m* in neutral.
>
> To obtain the remaining two speeds, slide the sun-wheel *g* into mesh with the planetary gear *e*, and hold the clutch cone *m* for the lowest forward speed and the brake-drum *j* for the reverse speed.

While correctly proportioned gear ratios are easily obtainable with the design shown in Fig. 11, the ratios in Fig. 13 are more difficult to arrange, it being impossible to obtain a direct drive on the top speed. It may be remarked, however, that a direct drive on the third speed with an indirect top speed has been successfully employed by certain automobile builders.

Rear Axle Design

Fig. 14 shows an epicyclic gear designed to form part of a rear-axle spur-type differential. Apart from the ordinary differential gears, the extra parts required are two sunwheels and two planetary-gears, these latter may be added to as desired, and with these few parts the gear is capable of providing four speeds forward and one reverse. The top forward speed, geared up, is, however, too high a ratio for ordinary road use.

The worm *a* drives the wormwheel *b* which is fixed to the differential easing. The spindle of the differential planetary gear *c* is extended to carry the planetary gear *d* meshing with the sun-wheel *e* which can be brought to rest by the brake-drum *f*. In the same way the spindle of the differential planetary gear *g* carries the planetary gear *h* meshing with *i* controlled by the brake-drum *j*. The rear-axle cross-shafts are of the floating type, and are arranged so that the sun-wheels *k* and *l* can be moved sideways by a change-speed lever and the usual selector mechanism. The brake drums *f* and *j* are controlled by two pedals.

The position of the gears in Fig. 14 shows the direct

drive in operation, the differential gear functioning as such in the usual manner, the drums *f* and *j* revolving at the same speed as the differential cage. When *k* is moved to the extreme left, so as to engage with the planetary gear *c*, two more speeds are available by locking the brake-drums *f* and *j* respectively. When *l* is moved to the extreme right, so as to engage with the planetary gear *g*, two more speeds are available by once again locking *f* and *j* respectively, thus providing a total range of four speeds forward and one reverse. On the indirect speeds the gears *c*, *g*, *k* and *l* cease to function as a differential.

Many motor trucks have been tested under the most strenuous conditions after their differential gears have been removed. It has been stated by W. O. Thomas[2] that

> These gave surprisingly good results, and instead of decreasing the tire mileage, as would be expected, the mileage appeared to increase. This could only be attributed to the decreased slip of the wheels on the granite block pavements and in the mud and holes near the front. These trucks would pull over almost impossible places, and were the best evidence of the need of limited action.

One of the earliest examples of a live axle designed to eliminate the bugbear of unsprung weight was the De Dion Bouton motor car, and the same design is still adhered to in the 1921 De Dion Bouton commercial vehicle. The design unfortunately necessitates the use of four universal-joints, two on each side of the rear axle casing, without taking the propeller shaft into account. Fig. 15 illustrates a method of eliminating unsprung weight in which only one universal-joint is required in place of the usual four.

In the plan view at the right of Fig. 15 the bevel casing *m* is suspended by a pivoted link *n* from the rear cross-member *o* of the chassis. The axle sleeve *p* terminates in a spherical ball *q* which allows the sleeve to have a universal movement with respect to the case *m*. The other half of the bevel casing, *r*, carries the axle sleeve *s*, the outer extremities of the two sleeves *s* and *p* carrying the rear road wheels in the usual manner.

It will be seen that this design not only insulates the transmission gear from all road shocks, and reduces the unsprung weight of the vehicle, but in addition provides each road wheel with independent motion when rising or falling over obstructions through the universal-joint *t* which is concentric with the ball joint *q* and which allows the shafting to adapt itself to the angularity of the axle sleeves caused by the irregular movement of the road wheels.

The disadvantages of the ordinary rear-axle suspension are illustrated by Fig. 16, where the dotted line shows the movement of the ordinary live axle when the left road wheel is passing over a 4-in. obstacle.

The exact movement of the body cannot be determined on paper, but obviously the ideal arrangement is for the body to remain absolutely horizontal, so that the passengers may not be thrown from side to side. In Fig. 16 the body is purposely drawn stationary to show the relative movements of the two axles. It will be noted that the center point of the ordinary axle has been displaced sideways as indicated by the letter *u*. The springs have also moved sideways a distance *v* and *w* or alternatively the body must be thrown sideways, while with the jointed axle the road springs remain practically vertical. There can be little doubt that the independent motion of the road wheels, obtained by the use of a jointed axle, will provide greater comfort for the occupants of the car and the reduction of unsprung weight will considerably prolong the life of the tires. In the De Dion Bouton design the only advantage appears to be that of the reduction of unsprung weight, as the movement of the road wheels resembles that of an ordinary axle.

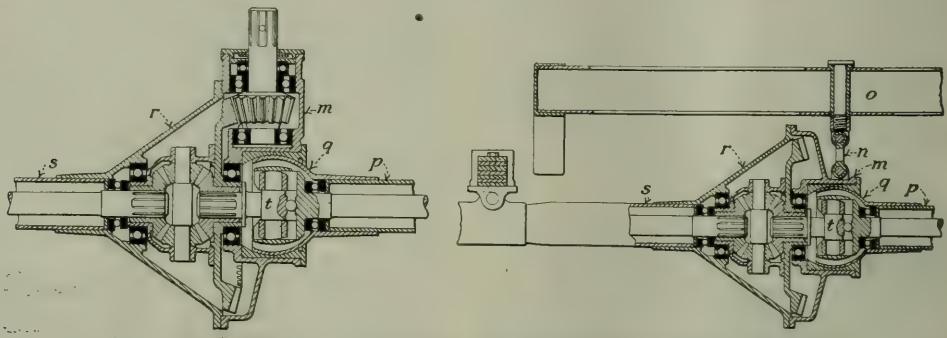


FIG. 15—END ELEVATION AT THE LEFT AND PLAN VIEW AT THE RIGHT OF AN EPICYCLIC REAR-AXLE

WORM GEAR DESIGN

Although the advantages and characteristic features of worm gear are now well understood, I have never yet come across any textbook which explains the real nature of the tooth contact between the worm and the wheel. Before discussing this subject in detail, the ground may be cleared by a few introductory remarks.

Circular pitch is measured circumferentially along the pitch circle of the worm wheel

Linear pitch is measured in a straight line parallel to the worm axis

Lead angle is the angle between a worm thread and a line drawn at right angles to the worm axis

Lead is the distance traveled by any point on the pitch circumference of the wheel for one revolution of the worm

Lead = Linear pitch × Number of threads

Tangent Lead Angle = Lead / (π × Pitch diameter of worm)

Pitch diameter of wheel = (Number of teeth × Circular pitch) / π

In an ordinary worm gear the axes of the worm and the wheel are at right angles, and under these conditions

[2] See THE JOURNAL, July, 1917, p. 29.

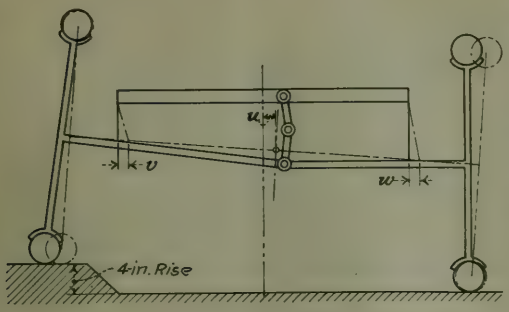


FIG. 16—DIAGRAM OF THE REAR-AXLE MOVEMENT IN PASSING OVER A 4-IN. OBSTACLE

the circular pitch of the wheel is equal to the linear pitch of the worm.

The gear ratio of worm gear is found by dividing the number of teeth in the wheel by the number of threads in the worm, yet, unlike spur or bevel gearing, the ratio is independent of the pitch diameters of the worm and the wheel. One concrete example will make this perfectly plain. Let a worm of 1.585-in. pitch diameter mesh with a wormwheel of 15.915-in. pitch diameter having 100 teeth of ½-in. circular pitch at 8.75-in. center distance. Then the gear ratio may be varied by varying the number of threads in the worm without altering the pitch diameters or the center distance. Some of the possible variations are given in Table 1.

TABLE 1—RELATION BETWEEN NUMBER OF THREADS IN A WORM AND THE LEAD ANGLE

Threads in worm	Gear ratio	Lead, in.	Worm angle, deg.	min.
1	100.0 to 1	0.5	5	44
2	50.0 to 1	1.0	11	21
4	25.0 to 1	2.0	21	53
6	16.7 to 1	3.0	31	04
8	12.5 to 1	4.0	38	47
10	10.0 to 1	5.0	45	07

In this table the pitch diameters and center distance remain unaltered. It will be seen that a large gear ratio, 100 to 1, necessitates a small lead angle, 5 deg. 44 min. and vice versa. The most efficient lead angle lies between 40 and 45 deg.

Some engineers calculate worm gears on the hit-or-miss principle. This is a mistake. The proposition is really very simple, if attacked in a systematic manner. Thus, required to design a worm gear with a ratio of 10 to 1, the size of the worm wheel being restricted to 16-in. pitch diameter on account of ground clearance.

$$\text{Lead} = (\text{Pitch diameter of wheel} \times \pi) / \text{Gear ratio}$$
$$= (16 \times \pi) / 10 = 5 \text{ in. approximately}$$

In other words, the lead *must* be 5 in., no matter what linear pitch, lead angle or pitch diameter of worm be chosen. The next most important factor is the lead angle. To obtain high efficiency select a high angle, say 40 deg. Then

$$\text{Pitch diameter of the worm} = \text{Lead} / (\text{Tangent of lead angle} \times \pi)$$
$$= 5 / (0.84 \times \pi) = 1.9 \text{ in.}$$

Hence a lead angle of 40 deg. cannot be used, because 1.9 in. is too small a diameter for such a large gear. Now ascertain the smallest diameter of worm shaft to withstand torque and bending, and select a pitch diameter to correspond, say 2.5 in. Then

$$\text{Tangent of the lead angle} = \text{Lead} / (\text{Pitch diameter of worm} \times \pi)$$
$$= 5 / (2.5 \times \pi) = 0.64$$

The angle having a tangent of 0.64 is approximately 33 deg. Thus, under the conditions given, the lead angle cannot exceed 33 deg., and the efficiency of the gear can be calculated accordingly.

The manner in which the lead angle varies according to the pitch diameter, with a given gear ratio and center distance, is illustrated in Table 2.

TABLE 2—RELATION BETWEEN THE LEAD ANGLE AND THE PITCH DIAMETER

Fixed gear ratio, 10 to 1 Fixed center distance, 8.75 in.

Wheel pitch diameter, in.	Worm pitch diameter, in.	Lead, in.	Lead angle deg.	min.
16.00	1.50	5.03	46	40
15.75	1.75	4.95	42	0
15.50	2.00	4.87	37	49
15.25	2.25	4.80	34	13
15.00	2.50	4.72	30	57
14.75	2.75	4.64	28	12
14.50	3.00	4.55	25	47

It need hardly be said that no gear should be selected without first consulting a maker's hob list in order that standard tools may be brought in.

When the shape of, or forces acting on, worm-gear teeth have been theoretically considered, it has been usual to take a linear section through the center of the worm at right angles to the wheel axis. On this axial plane it has been customary to make the shape of the gear teeth to correspond with those of a rack engaging with an ordinary spur, thus providing an involute tooth profile on this particular section. But what is taking place on adjacent parallel planes?

The shape of the teeth of a rack-shaped worm, on one of these corresponding parallel sections, is peculiarly curved, and the wheel teeth, on these planes, should be conjugate to suit, but this is impossible owing to interference. On these other planes the wormwheel teeth are concave, in order that they may wrap round the threads of the worm, so that corresponding sections, on either side of the axial plane, in no way resemble the involute shape of tooth. Hence it follows that the transmission

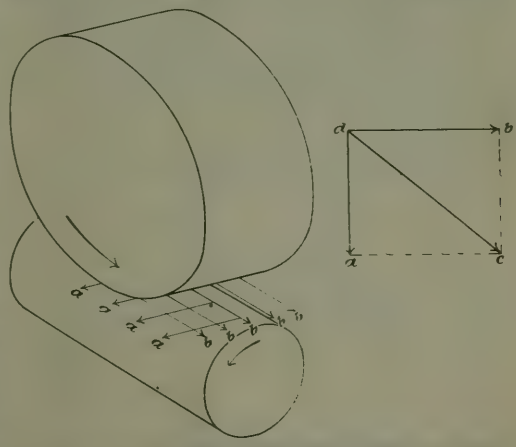


FIG. 17—DIAGRAM SHOWING THE RELATION BETWEEN THE TORQUE ON THE WORM AND THE WORMWHEEL AT THE LEFT AND THE RESOLUTION OF THE FORCES AT THE RIGHT

of true uniform velocity, which is a characteristic of the involute gear, applies only to a section on the axial plane where the worm section is that of a rack. The constructive problem of the nature of the tooth contact on these other planes has, it is believed, never before been properly investigated. It can, however, be successfully solved by the application of the principle of the parallelogram of forces which must hold good at every point where tooth contact takes place, and the application should be applied to every single phase of tooth contact, and not merely limited to one axial plane as has been the practice heretofore.

The pitch surfaces of the worm and the wheel are both cylinders, and can therefore only touch at one point. The torque on the worm can be represented by a force *a*, acting longitudinally anywhere on the pitch surface, and in a tangential direction, as shown in Fig. 17. In the same way the torque on the wheel can be represented by a force *b* acting in the same manner.

To obtain the transmission of uniform velocity between the worm and the wheel, it is necessary that the resultant force *c*, normal to the tooth surfaces at their point of contact, shall be capable of being resolved into two components, *a* and *b*, both of which must always be tangential to their respective pitch cylinders and at right angles to their axes, these three forces all lying, of course, on the same plane. For if the resultant *c* can be resolved into two components either of which do not touch their respective pitch cylinders, the instantaneous torques on the two gears will not correspond to the velocity ratio. But the velocity ratio is determined by the threads of the worm and the teeth of the wheel, which is obviously a constant quantity; hence, when the respective torques of the worm and the wheel do not correspond to the gear ratio, the transmission of true uniform velocity will be impaired, the slight accelerations and retardations having to be absorbed by the elasticity of the gear teeth, thus lowering the efficiency of the gear and causing undue wear.

To secure uniform velocity transmission between the worm and the wheel, the constructive problem of building up the correct tooth contours may, therefore, be stated as follows:

(1) Select a series of resultant forces capable of being resolved into components which must always be tangential to their respective pitch cylinders
(2) From a series of such resultants build up a tooth contour, working on the well-known fact that all resultants must always be normal to the tooth surfaces at their respective points of contact

In drawing at the right of Fig. 17, *a* and *b* represent the tangential forces acting on the pitch cylinder of the worm and the wheel respectively about the point *d*, and *c* is the resultant of these, acting in the plane containing *a* and *b*. The relation between *a* and *b*, being determined by the ratio of the gears, is bound to remain constant, so that the angle which *c* makes to the axis of the worm will also remain constant.

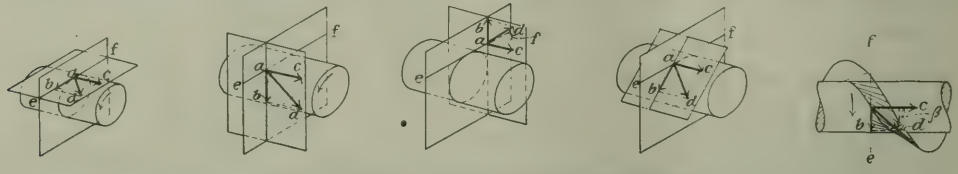


FIG. 18—DIAGRAM OF FORCES ACTING IN VARIOUS PLANES
From Left to Right in a Horizontal Plane, the Near Side of a Vertical Plane, the Far Side of a Vertical Plane, an Inclined Plane and the Series of Resultants Obtained

DETERMINATION OF POINTS OF CONTACT

At the left of Fig. 18 is shown a simple application of these forces, the point *a* being the contact point of the two cylinders lying on a "central plane" at right angles to the worm axis and containing the wheel axis. In this particular case the plane *bcd* is tangential to both cylinders. The next drawing represents a view of the same plane when moved through 90 deg. round the worm pitch cylinder, the point *a* still being on the pitch cylinder of the wheel and also on the central plane so that *c* may still remain tangential to the wheel. The middle diagram is a similar view when the plane is moved around the pitch cylinder in the opposite direction.

In all these three cases it will be observed that *c* is tangential to the wheel cylinder, and that both *b* and *d* are, in every case, tangential to the worm cylinder. It will be further noted that the point *a* in each case lies on the line of intersection of the wheel cylinder and the central plane. When these conditions are fulfilled, and the angle β remains constant, three points of contact are obtained.

It is now necessary to ascertain all the possible intermediate positions in which the fundamental conditions still obtain. Let *ef* be a line on the central plane tangential to the worm cylinder. Then the requisite conditions are fulfilled if the center *a* of the forces always lies on *ef*, and the plane is always tangential to the worm cylinder and in such a position that the force *b*, acting at right angles to the axis of the worm, is always tangential to its cylinder, the same relation holding good between *c* and its wheel cylinder. Such an intermediate example is illustrated in next to the last drawing, and that at the extreme right shows a series of resultants forming a "zone of contact" which contains all the possible points of contact and provides for the correct relation between *b* and *c*. As the resultants *d* are tangential to the worm cylinder, it follows that they only touch at one point; hence beyond this point they project outward and

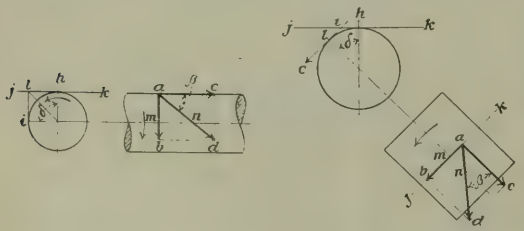


FIG. 19—DETERMINATION OF A POINT OF CONTACT ON THE PITCH CYLINDER AT THE LEFT WHEN δ EQUALS 90 DEG. AND AT THE RIGHT WHEN IT IS LESS THAN 90 DEG.

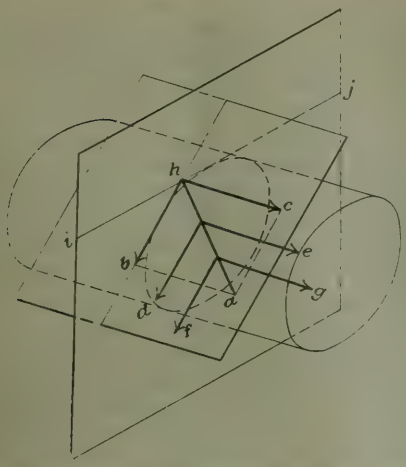


FIG. 20—FORCES ACTING IN AN INCLINED PLANE WITH A SERIES OF COMPONENTS

provide for points of contact outside or beyond the periphery of the worm cylinder. These external points of contact necessitate the building up of a tooth, the contour of which is controlled by the zone of contact, the latter being normal to the tooth surfaces at their respective points of contact. From the above it will be obvious that the zone of contact does not lie on the periphery of the worm cylinder, but stands proud in the form of a twisted ribbon. It is, in fact, a series of innumerable straight lines which, combined together, provide a curved surface, all these lines being tangential to the worm cylinder and lying at a constant angle β to the worm axis in addition to cutting the line *ef* on the central plane.

In Fig. 19 it will be obvious that one point of contact is on the central plane at the point of contact *h* between the two cylinders. Move the contact point through an angle δ equal to 90 deg. Then the point of contact will have moved in the end view to the point *i*.

In the same view draw *jk* tangential to the worm cylinder at the point *h*, and draw *il* at right angles to it. Project a side view looking in the direction *jk* and let *a* be the intersection of the forces *b* and *c*, as before. The point *a* lies on the line *jk* which is contained by the central plane. Draw the resultant *d* and project *i* until it cuts *ab* at *m* and intersects the resultant *d* at *n*. Then *n*, being on the resultant *d*, and also on the pitch cylinder, is the position of the point of contact after it has been moved through 90 deg., and the length *mn* is its distance from the central plane.

Then

$$mn = am \cot \beta$$

and

$$am = li = \text{Radius} \times \tan \tfrac{1}{2} \delta$$

therefore

$$mn = \text{Radius} \times \tan \tfrac{1}{2} \delta \cot \beta$$

At the right of Fig. 19 the angle δ is less than 90 deg. Draw *jk* as before and from *i* draw *il* tangential to the worm cylinder at the point *i* and cutting *jk* at *l*. Project a view on a plane parallel to *il* and project *l* to cut *jk* at the point *a*. From *a* draw the forces *b*, *c* and *d* as before. Project *i* until it cuts *ab* at *m* and intersects the resultant *d* at *n*. Then *n* is the point of contact and *mn* its distance from the central plane.

Then

$$mn = \text{Radius} \times \tan \tfrac{1}{2} \delta \cot \beta$$

as before.

As *a* is the single force which produces the same effect as the combined action of the two forces *b* and *c*, and as *a* may be resolved into any two forces such as *d* and *e* or *f* and *g*, it follows that *b* and *c* may act at any point in the same plane along *a* as shown by the diagram in Fig. 20. Hence the contact point between the worm and wheel can lie anywhere along the resultant *a*, and the effective result will be the same as if the components originated from *h* and the line *ij*. It is therefore possible to have contact outside the worm cylinder at any point along *a*.

Although the contact point lies along a certain resultant, the position of this point will vary according to the rotation of the worm. The zone of contact will always remain stationary, owing to the fact that the positions of the resultants are definitely determined by their intersections with the stationary line *ij*, the latter being independent of any rotary movement of the worm gear. The actual points of contact will be the intersection of the worm tooth and the zone. It is therefore necessary to ascertain, in accordance with the rotation of the worm, the location of the points of contact along the resultants *a* on any outside portion of the worm thread.

Let *m* (Fig. 21) be any such point located at any radius *nm* from the axis of the worm and making any angle δ with a plane *no* containing the worm axis and at right angles to the wheel axis.

From *m* draw *mp* tangential to the worm pitch cylinder in a direction opposite to the supposed rotation of the worm, so that *pm* represents the force *q*. This line intersects *rs* at *t*. Project a view on a plane parallel to *pm* and complete the construction as in the case of Fig. 19. From *m* draw *mv* parallel to *rs* meeting *no* at *w*. Draw *wx* parallel to *mb* intersecting the line *rs* at *x*. Then, as before, *y* is the new point of contact and *zy* its distance from the central plane.

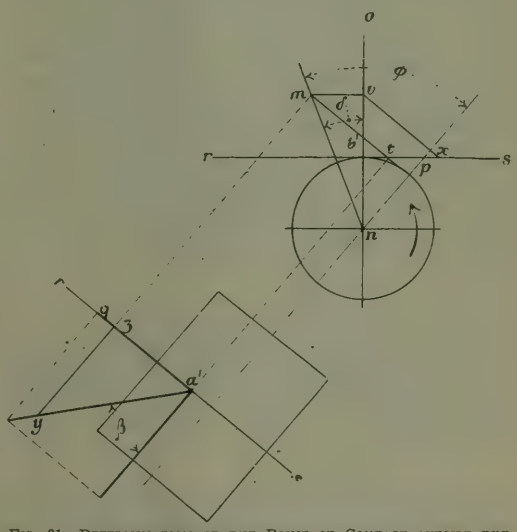


FIG. 21—DETERMINATION OF THE POINT OF CONTACT OUTSIDE THE PITCH CYLINDER WHEN δ IS LESS THAN 90 DEG.

Then

$$zy = a'z \cot \beta$$

and

$$za' = tm = vx$$

Let

$$\angle pnm = \phi$$

Then

$$\angle pnv = \phi - \delta$$

but

$$\angle pnv = \angle vxb'$$

Therefore

$$\angle vxb' = \phi - \delta$$

Now

$$xv = vb' / \sin (\phi - \delta)$$

but

$$vb' = vn - nb'$$

and

$$vn = nm \cos \delta$$

Therefore

$$vb' = nm \cos \delta - nb'$$

Hence

$$xv = (nm \cos \delta - nb') \div \sin (\phi - \delta)$$

As

$$xv = a'z'$$

therefore

$$zy = [(nm \cos \delta - nb') \div \sin (\phi - \delta)] \cot \beta$$

so that

$$zy = \cot \beta \,[(\text{Radius of contact point} \times \cos \delta) - \text{Pitch of radius cylinder}] \div \sin (\phi - \delta)$$

Note that when the point of contact is on the pitch cylinder

$$zy = \frac{\text{Radius of pitch cylinder} \times \cos (\delta - 1)}{\sin (0 - \delta)} \cot \beta.$$

$$= \frac{\text{Radius of pitch cylinder} \times \cos (\delta - 1)}{\sin - \delta} \cot \beta.$$

$$= \text{Radius of pitch cylinder} \times \tan \tfrac{1}{2} \delta \cot \beta$$

as already shown in connection with Fig. 19.

Straight Line Generation

Let *ab* be the surface of the worm thread moving in the direction of the arrow as shown in the diagram at the left of Fig. 22, and let *c*, *b* and *e* represent the forces acting on it. If the worm thread *ab* be moved at a uniform rate longitudinally, parallel to its axis, in the direction of the arrow as shown, it would drive the worm wheel in exactly the same manner as if it were caused to rotate at a uniform rate, because all linear sections are identical. If, therefore, the worm rotate uniformly in the direction *c*, the point *a* will move uniformly in the direction *d;* hence the point of contact between the worm and the wheel must move uniformly along the resultant *e*.

Now the line *ae* touches the worm cylinder only at the point *a*. Any other point of contact between the worm and the wheel along the resultant *e* will therefore be on a portion of the worm thread projecting above the worm cylinder. But *e* is in the horizontal plane defined by *d* and *c*, and as any point of contact along *e* is an intersection of the worm thread *ab* and the resultant *ae*, it follows that the worm thread must be of such a contour that it lies along a straight line *ab* at right angles to *e* and therefore inclined at an angle β to the plane *fg*. Clearly the angle β is equal to the lead angle of the worm.

The other diagram shows the positions of the straight lines *hi* and *hj*, corresponding to *ab* on the threads of a left-handed worm. It is interesting to note that, with this new design of worm gear, there is no thread below the pitch line of the worm, and consequently throat diameters and pitch diameters of worm wheels are identical.

The threads of the ordinary parallel type of worm gear are made straight-sided on a linear section through the center of the worm at right angles to the wheel axis.

It is well known that the tangent of the circular pressure angle at any radius equals the tangent of the linear pressure angle multiplied by the cotangent of the lead angle at the same radius. The circular pressure angle is, of course, shown in the end view of the worm, tangential to the tooth contour at its point of contact.

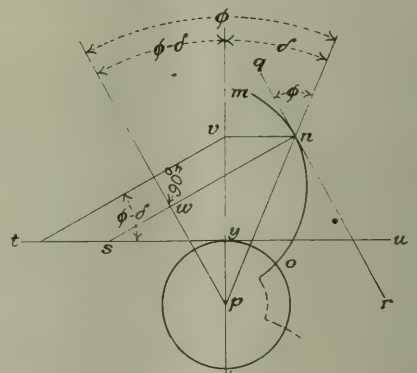


Fig. 23—Determination of Points of Contact outside the Pitch Cylinder of the Ordinary Type Worm Gear

To draw a diagram of the zone of contact of the ordinary type worm gear it is necessary to ascertain the distance of various points of contact at various radii from the central plane. These may be ascertained by drawing a diagram similar to that shown in Fig. 21. Thus, in Fig. 23 let *mno* be the end view of a portion of the worm thread from which it is required to ascertain the distance of the point of contact *n*, on any radius *pn* situated at any angle δ from the central plane. Draw *qnr* at the circular pressure angle φ to the radius *pn*. From *n* draw *ns* perpendicular to *qnr*. Then *ns* represents the normal to the tooth at its point of contact.

Now *ns* cuts the line *tu* at *s*. From *n* draw *no* parallel to *tu* and *vt* parallel to *ns*. Then the angle *vtu* equals the angle $nsu = \varphi - \delta$. As before the distance *x* equals *ns* multiplied by the cotangent of the lead angle on the radius *pw*, but

$$ns = vt = vy / \sin (\phi - \delta)$$

and

$$vy = ns \cos \delta - ey$$

therefore

$$x = [ns \cos \delta - ey \div \sin (\phi - \delta)] \text{ cotangent of lead angle on radius } pw$$

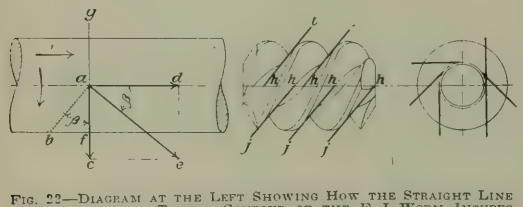


Fig. 22—Diagram at the Left Showing How the Straight Line *ab* Lying on the Thread Contour of the F J Worm Insures Uniform Velocity Transmission and at the Right a Plan of the F J Worm Indicating the System of Straight-Line Generation

From this formula the curves shown in the left half of Fig. 24 have been plotted, and from the formulas already given in connection with Figs. 19 to 21 the graphs shown in right half have been plotted. These show the lines of contact along the zone for the F J worm gear.

Comparison of the Two Types of Worm Gear

The two portions of Fig. 24 should be carefully compared. In left half, which shows the lines of contact for the ordinary type of worm gear, the zone of contact is actually interrupted near the central plane, and almost the entire contact takes place on the approaching side of the wormwheel, which means that if the worm be placed in engagement with the wheel, contact between their teeth takes place on the extremities of the worm, when, in many cases, the center teeth have practically no contact. There is also a duality of the lines of contact, which, during the revolution of the gear, gradually travel towards each other, meeting just beyond the central plane where contact entirely ceases.

In the right half of Fig. 24, which shows the zone of contact for the F J worm gear, it will be noticed that the lines of contact are regular and uniform, with no duality and no objectionable interruption. The left half demonstrates the very imperfect form of tooth contact obtained from the ordinary type of worm gear, which is straight-sided on the linear section. In the year 1913 both F. J. Bostock and myself knew of these defects. The solution and the remedy were, however, discovered by Mr. Bostock, and it was entirely due to his efforts, in conjunction with the facilities afforded by David Brown & Sons, that this new form of F J worm gear has been evolved. I had the privilege, however, of watching the mathematical development of the present invention, which entailed great labor and occupied many months, a brief outline of which has now been made public for the first time.

The difference between the ordinary and the F J type of worm gear can be best illustrated, to those who are not keenly interested in mathematics, by taking a concrete example of each case as shown in the four sections of Fig. 25. These illustrations show two plan views of each type of worm, together with a sectional view of each worm in mesh with its wormwheel just above. The two views in the left half show the nature of the contact between an ordinary type of worm and wheel, that at the extreme left showing the worm in such a position that the drive is taken by the two threads *a* and *b*, while the next one shows a different position, the worm having been rotated through an angle of 45 deg., thus causing the thread *a* to carry the entire load. The ribbon-like area, outlined on the plan view and stretching across the

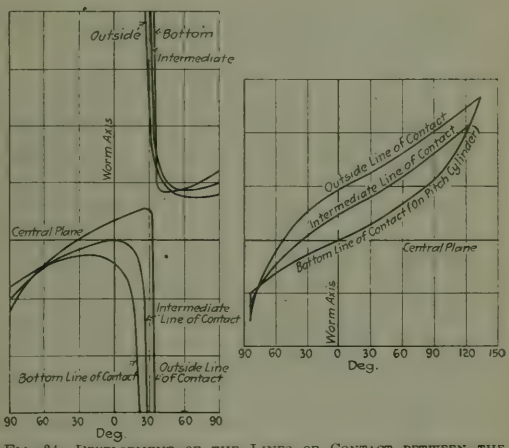


Fig. 24—Development of the Lines of Contact between the Worm and Wormwheel at the Left with the Ordinary Type of Worm Gear and at the Right with the F J Type of Worm Gear

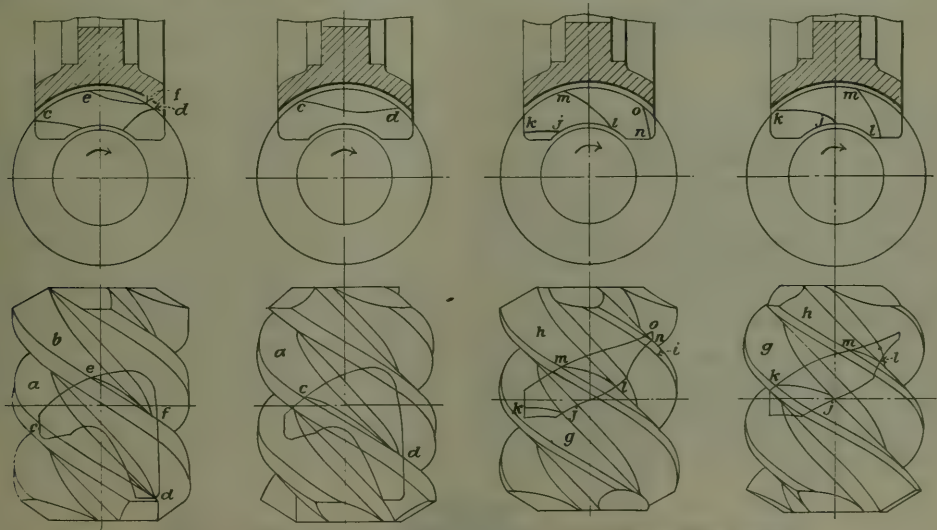


Fig. 25—Difference between the Ordinary and the F J Types of Worm Gears

At the Left the Zone of Contact between the Ordinary Type of Worm and Wormwheel Is Shown and in the Next Section to the Right Is Portrayed the New Position of the Worm Threads after a Rotation of 45 Deg. The Two Views in the Right Half of the Illustration Are the Corresponding Positions of F J Worm and Wormwheel

threads of the worm, marks the "zone of contact" between the gears when the worm is rotated in the direction of the arrow shown in the end view. The intersections of the worm threads and the zone give the lines of contact between the worm and wheel teeth, and at no point outside this zone is there any contact between the worm and the wheel. At the left of Fig. 25 the actual contact between the worm thread *a* and the wheel is marked by the line *cd*, and that between the worm thread *b* and the wheel by the line *ef*. After the worm has been rotated to an angle of 45 deg., as shown by the second drawing, there is only one line of contact between the worm and the wheel as indicated by the line marked *cd*. It will be noted that the lines of contact in both end views in the two drawings are unsymmetrical, and this irregular contact is detrimental to the running of the gears.

The two drawings in the right portion of Fig. 25 show the zone of contact with David Brown & Sons' new type of F J worm gear. The plan view in the first of these shows the worm in such a position that the drive is taken by the three threads *g*, *h* and *i*, while the other shows the two threads *g* and *h* in simultaneous contact with the wormwheel. The actual lines of contact between the worm and the wheel in the first case are marked *jk*, *lm*, and *no*, while in the other, after the worm has been rotated through an angle of 45 deg., the new lines of contact are shown by the line *jk* and *lm*. With this design of worm gear the regularity of the lines of contact as shown in the end view is in marked contrast to that of the contact lines shown in the other half of the illustration.

The worms illustrated in Fig. 25 are as alike as possible, both types having four threads, the only real difference between them being in the shape of the tooth contour. In both cases whenever the worm is revolved through an angle of 90 deg., the line of contact *jk* will sweep across the zone of contact until it takes up the position of *lm*, because when a four-threaded worm moves a quarter of a revolution or 90 deg. the thread *g* will naturally take up the position of the thread *h*. In the F J system it will be seen that the point *j* at the root of the worm in the end view falls into the position *k* after a quarter of a revolution as shown at the extreme right of the illustration. Thus, the actual contact travels in the same direction as the worm, and this new action between the teeth of the gears reduces the ordinary rubbing velocity to a minimum, which decreases frictional losses and consequently increases the efficiency of the drive to a very marked degree.

With the ordinary parallel type of worm gear, however, the point of contact *d* actually moves in the opposite direction to the rotation of the worm to the point *f*, thereby increasing the rubbing velocity. One of the peculiar characteristics of the ordinary type is that the extremities of the lines of contact as shown in the plan view of the worm at the extreme left, travel from the position *c* and *d* toward each other until they meet and vanish just beyond the point *e* and *f*.

The end view of the F J system in the third drawing shows the point *k* always moving from left to right, in the same direction as the rotation of the worm, while with the ordinary type the point *d* moves very slightly from right to left, actually against the rotation of the worm. The high rubbing velocity which occurs on the points *d* and *f* together with the converging lines of contact which induce a concentrated load, all tend to produce the worst possible conditions on the leaving side of the wormwheel. This explains the well-known fact that when a worm gear of the ordinary type is overloaded, or is imperfectly lubricated, pitting first takes place on the leaving side of the wheel, and on this side only, while those portions of the teeth on the entering side remain unmarked. It is believed that this is the first time that this phenomenon of uneven wear on the teeth of the wormwheel of the ordinary parallel system has been fully explained.

CURRENT AND VOLTAGE VALUES IN A BATTERY

(*Concluded from page* 327)

of the flywheel system from one revolution to another, which cannot be done by a tachometer.

Fig. 17 shows the characteristics of the charging current at varying speeds, as observed on the Dodge car. The starter system was North-East Model D. In the upper section of this illustration the speed was low, but in the lower it is much higher. The engine speed can be computed as described above. These curves are shown here to illustrate the applications of this method of measurement rather than to give quantitative measurements on this starter or system.

Conclusions and Summary

This investigation was begun to study the demands upon starting and lighting batteries in the operation of various types of automobile. Illustrations of the oscillograms obtained for five of the cars measured have been included in this paper. Some of these cars belong to private individuals and some to the Motor Transport Corps. We acknowledge our indebtedness to them and particularly to Dr. H. C. Dickinson of the Bureau of Standards and Majors M. O. Boone and G. H. Totten of the Motor Transport Corps. The special camera was devised by Dr. J. C. Karcher.

The results obtained enable us to determine the instantaneous values of current and voltage when the starting system is in operation. The interpretation of the records has indicated also the possibility of using this method for the study of lubrication and engine problems relating to speed, friction, ignition, compression, distributor action, etc. A large number of oscillograms illustrating these applications have been given. These are intended to be suggestive rather than quantitative measurements of performance, since the observations were all made on cars in running condition, without fixed orifices on the carbureter or a constant-speed control.

Third Semi-Annual Gasoline Survey

THE first survey of fuel gasolines sold throughout the United States was made by the Bureau of Mines in 1915. This was followed by another in 1917 and a third in April, 1919, which showed that the gasoline had become notably less volatile during each 2-year interval. To ascertain whether this change was

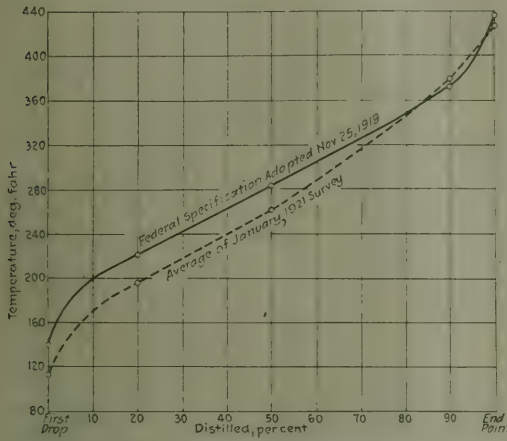


FIG. 1—DISTILLATION CURVE OF THE AVERAGE OF THE SAMPLES OBTAINED IN THE THIRD SEMI-ANNUAL GASOLINE SURVEY AND ONE BASED UPON THE FEDERAL SPECIFICATION ADOPTED NOV. 25, 1919

continuing semi-annual surveys were made in January and July, 1920, and in January, 1921. In the January, 1920, survey it was found that the average volatility of the gasoline was practically identical with that tested in April, 1919. The survey made in July, 1920, the results of which were given in THE JOURNAL,[1] showed a very marked decrease in the volatility but as it is a matter of common knowledge in the petroleum industry that the volatility of gasoline sold in the summer months is less than that of the fuel made and sold in the winter, part of the change was attributed to this fact.

In the recently completed survey 115 samples were collected and analyzed. It was found that the average boiling point of these samples was 263 deg. fahr. as compared with 264 a year ago, which shows that the average gasoline marketed at the present time is fully as volatile as that sold a year ago. A noticeable change in the character of the product has, however, occurred, the initial boiling and 20 per cent points being lower than a year ago, while the 90 per cent and end-points are higher which indicates a greater proportion of gasolines made by blending casinghead or natural gas-gasoline and naphtha. This change in the character of internal-combustion engine gasoline is brought out in the accompanying illustrations. Fig. 1 shows a distillation curve based on the average figures of the present survey together with a similar curve based on the Federal specification adopted Nov. 25, 1919. In this connection it will be noticed that the distillation curve for the recent survey is higher than the specification curve at the 90 per cent point. Fig. 2 presents the upper ends of the curves of the averages of the three surveys and the Federal specification previously mentioned. This illustration brings out in a striking manner the change noted from January to July, 1920, which was due particularly to the normal change from winter to summer quality and also to a permanent change in the character

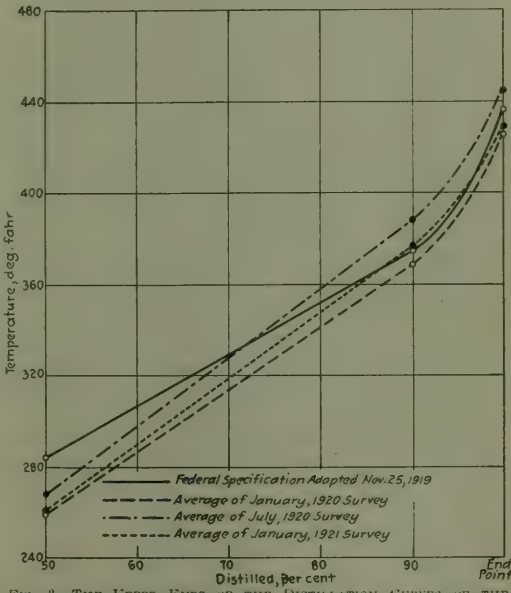

Temperature, deg. fahr
Distilled, per cent
End Point
Federal Specification Adopted Nov. 25, 1919
Average of January, 1920 Survey
Average of July, 1920 Survey
Average of January, 1921 Survey

FIG. 2—THE UPPER ENDS OF THE DISTILLATION CURVES OF THE AVERAGE OF THE THREE GASOLINE SURVEYS AND THAT SPECIFIED BY THE FEDERAL GOVERNMENT

of the gasoline. The increase in the 90 per cent point probably means that the refiners are including more high boiling material in the gasoline while at the same time they apparently are getting closer fractionation in the distilling process as the end-point is not being increased as much as the 90 per cent point.

[1] See THE JOURNAL, September, 1920, p. 300.

The Body Engineer and His Relation to the Automotive Industry

By Kingston Forbes[1]

Annual Meeting Paper

IN choosing the title of this paper it was hoped that a note could be struck which would bring to the attention of the industry the breadth and scope of body engineering and outline the way this side of the industry can be considered and developed. Body engineering must, of course, depend on mass production or big business for its greatest encouragement. In small-scale production small items can be handled very easily, but in large productions they are of tremendous importance. If 1000 cars are scheduled to be made in a day and a shortage occurs in one of the smallest items, the entire production may be held up, incurring a loss of thousands of dollars. This emphasizes the importance of every detail in large business in a way that no one can fail to grasp. For instance, if a change in design could be made by the body engineer that would permit cutting the leather for the trimming to 15 per cent waste instead of 20, a saving of $1,000 and over per day would be made in a daily car production of 1000. In a small shop or custom shop a few feet of leather more or less would not make much difference.

The field of body engineering is broader than it is ordinarily considered to be. The body engineer's relation to a body building plant, large and small car plants and a custom shop, demands different classes of engineers. In the main the body engineer is responsible for the external appearance of the entire car. If it is a custom-built job, a preliminary sketch of the complete car is made, and very often this is all the body builder, top maker and trimmer have to work on; the car is made to look as much like the sketch as possible. A body plant very often submits designs for a complete car, but generally has only the body to build. To work out his ideas or combination of ideas the body engineer of the small plant relies to a great extent on the companies which build his bodies. In a large plant where bodies and all other metal parts are made, the body engineer has to consider the manufacturing details involved in all parts that he designs. There is a distinct difference between the mechanical side of the automobile and the general appearance or the artistic side. One would not ordinarily combine the story writer and the illustrator in more than a cooperative spirit. The success of the story does not depend upon the illustrations, or vice versa. But having a good story properly illustrated gives a wider field for its sale. So it is with a car; the mechanical condition and limitations have to be taken in hand by the body engineer. As a first qualification the car must be artistic. This is demonstrated by the 1921 cars. The body engineer of a company specializing in custom work must apply artistic principles in every body he designs; each car demands individuality and draws heavily on his power of creation. In the case of large production, a body designer has to satisfy 100,000 people with perhaps one model. We know that the tastes of 100,000 people are not all the same, although some of our movie stars have an unlimited following. The design for the 100,000 is not the most stylish design, but the one that will be most acceptable to the majority.

Customers often say that a given car does not quite suit and specify some favored characteristic. But few will agree on any specific design. But if a car of established popularity is shown, practically all will be satisfied with it. The point I wish to make is that simplicity of design and absence of jarring notes can be evolved only by painstaking effort. The layman cannot appreciate the work behind the smoothly finished product. The effort is not evident as with carvings and intricate embellished curves on historic buildings and churches.

Conflict Between Art and Economy

Art as applied to an automobile has to be manifested in the arrangement and shaping of sheet metal or other units on frames. Whether the result required be accomplished in economical manufacture has to be considered. The production of one thousand or more cars a day does not permit fancy hand decoration or carvings. Art has to be satisfied by huge presses and metal-forming machines. To achieve results, the practical sense of the body engineer must be as keen as his artistic ability; they must be coordinated to avoid disappointment. While there are definite conceptions upon which the artist bases his work, his success does not depend upon geometrically arranged lines, nor can the composition of his pictures be worked out with a slide rule. The mechanical side of the car is amenable to slide-rule practice, but the body lines are not. This is one reason body engineering has an indefinite position in the industry.

In large production it is not possible to control the metal parts in very fine degree, owing to variation in the grades of metal and the fluctuations in the operation of the presses. The upholstering, top design and painting, including enameling, all have a bearing on the final results. The main trades involved in body engineering are wood-working, sheet-metal working, metal machine-work, brace and hardware trimming, top building, painting and enameling. The body engineer should be familiar with all these trades. None of them can be learned by correspondence courses. In fact, there are practically no schools or instruction books covering the modern phases of the work.

A body engineering department can be classified in six main divisions.

(1) Body construction, open and closed
(2) Sheet metal, body metal, fenders, hood, radiators, etc.
(3) Trimming
(4) Top building
(5) General hardware
(6) Painting and enameling

[1] M.S.A.E.—Assistant body engineer, Buick Motor Co., Flint, Mich.

All the arts pertaining to the six divisions dovetail into one another and must have weight in the preliminary design. For instance, the radiator and hood can be considered the starting point for the body design; when these are established the main body construction is worked out from the dash or cowl-line back. The exterior lines of the body must be pleasing to the eye; at the same time the passenger capacity has to be ample and the comfort adequate. Satisfactory trimming has to be arranged for. Comfort depends upon leg-room, body-room and positions and well-arranged cushions and back springs with soft padding with suitable cloth, plush and leather covering. Passing on to the top, if it is an open body, the lines and windshield must be considered to permit a top to be made that will give proper protection and at the same time be pleasing in appearance and of course harmonize with the rest of the car.

The fenders and side aprons and radiators and mud-pans can add or detract much from a car's appearance, and must be worked out to blend with the other larger elements in car craftsmanship. Under general hardware come numerous small parts such as window regulators, door-locks, windshield hinges, not very large in themselves but important in providing ease of operation and satisfactory service. What is more annoying on a car than defective locks, rattling doors and hard-working or leaky windshields? Last but not least comes the painting. When this is done properly it adds tremendously to the final results. The panels, molding and corners should be made so that painting will be simplified. Sprays and flowing operations are used in modern mass-production methods; bad corners, moldings and holes will interfere seriously with the paint and cause varnish and dirt runs. If it is planned to have molding in color different from that of the main panels, it must harmonize and not produce discordant lines.

Need for Attention to Details

I have endeavored to indicate the breadth of the body engineering field. As the production increases, accuracy in details becomes more and more necessary. An organized department is required to handle this work. The grouping previously referred to can be made into department divisions, controlled by a separate engineer if the amount of work warrants it, with one or more men to keep the work in progress. Also a general drafting force with chief draftsman and checker are required.

Modern accounting and production demand minute information about every piece that goes to make up a car, and this entails a great amount of detail drafting work. Every piece of wood, top and side-curtain material, reinforcement, ragboards and wadding, trim material, leather, artificial leather, binding, ounce of hair, tacks, nails, and every screw, nail and piece of hardware mean that engineering information is required with the blueprints and specifications. The old method was to make paper patterns of all of the parts and let the manufacturing departments control their own work; whenever duplication of parts was required, additional paper patterns were made and sent out. Long ago it was found that no progress could be made in manufacturing without proper engineering records and blueprints.

I venture to say that there are several modern automobile plants that have no definite engineering control of the material purchased and fabricated in the groups outlined. This material runs into millions of dollars per year.

While the art of coach-building is as old as the ages, it was brought to a manufacturing basis only a few years ago when buggy production hit its high mark. The advent of the automobile brought entirely new problems. The automobile body engineer is a recent recruit in the engineering profession. His importance can be measured by his designs and by his control of body materials and their fabrication. It is not sufficient that a beautiful and readily marketable design be produced; it must be possible to make it economically and without waste of material. The future holds big opportunities for the body builder and engineer. Competition will be keener than ever, not only among the body builders, but among the car builders. The automobile competition will be the body engineer's opportunity. With the stabilizing of chassis construction, the external body and allied construction will become one of the biggest factors in marketability and the stimulating of sales.

There is opportunity for bringing the materials used in body construction to definite standards. A few of the items that could be considered seriously in this connection are lumber specifications, cushion-spring wire, fabricated cotton hair, burlap, imitation leather, top materials, webbings, closed body and windshield glass, automobile hardware, body bolts, curtain fasteners, bow sockets, top hardware, bow bendings, back curtain lights and door-handles.

DECEMBER REFINERY STATISTICS

THE production of gasoline for the month of December, 1920, was 464,393,356 gal. according to the monthly report of refinery statistics compiled by the Bureau of Mines, compared with 452,642,125 gal. in November, 1920. The average daily rate of production in December was 14,980,431 gal., as compared with 15,088,071 gal. in November and 10,827,729 gal. in December, 1919. The quantity of gasoline stored in the various refineries on Dec. 31, 1920, was 462,381,837 gal. as compared with 354,835,764 gal. on Nov. 30, 1920, and 446,793,431 gal. on Dec. 31, 1919. The stocks on hand at the various refineries scattered throughout the United States at the end of December were approximately 108,000,000 gal. more than on Nov. 30, 1920, and 16,000,000 gal. more than on Dec. 31, 1919.

Gas and fuel oil was the only one of the minor petroleum products to register an increase in the total production, the figures being 859,131,359 gal. for December and 822,638,305 gal. for November. The production of kerosene in December amounted to 210,668,109 gal. against 214,804,177 gal. in November. In the month of December 90,894,798 gal. of lubricating oil was produced as against 91,180,007 gal. in the month of November. The stocks of kerosene on hand at the end of December were 393,070,923 gal. as compared with 398,991,592 gal. on Nov. 30, 1920. At the end of 1920 the stocks of gas and fuel oil amounted to 837,404,414 gal. as compared with 808,802,516 gal. on Nov. 30, 1920. The stock of lubricating oils stored at the various refineries on Dec. 31, 1920, amounted to 160,522,477 gal. against 142,180,775 gal. one month previous.

In the month of December 328 refineries with a daily capacity of 1,174,395 bbl. of crude oil were in operation. This represents an increase in the number of refineries of 2 and 16,100 bbl. in the daily capacity as compared with the previous month.

High-Speed Engines of Small Piston Displacement

By Louis Chevrolet[1] and C. W. Van Ranst[2]

Indiana Section Paper *Illustrated with* Drawing and Photographs

FUEL economy is one important reason for the high-speed engine of small piston displacement. Gasoline was little thought of 25 years ago; the idea that some day we might be without it was a matter of small interest. To-day, conditions have changed. The automobile has advanced beyond all expectations and the consumption of gasoline has increased in like proportion. A comparison of the price ratio between gasoline and the automobile of 10 years ago with the ratio of to-day shows that the automobile has advanced very little, but that gasoline has advanced from three to four times the former price. The low cost of fuel is one reason that has enabled us to carry on large automobile production in this country. What will happen if the cost of this fuel goes beyond the reach of the buying public? The large production of automobiles which we have been enjoying will be cut down materially and conditions will parallel those of Europe. What good will it do to build cars at a low price, if the cost of maintenance is beyond the reach of the middle classes? The conservation of fuel is a foundation for large production. Unless the car builder works to that end, or the petroleum producers find a substitute fuel, the automotive industry will suffer.

In addition to using less pounds of fuel per horsepower-hour, the small high-speed engine has important features. One is that of light weight, which is a great step toward economy; less power is required to propel the car, less tractive effort is needed and the strain on the tires is not so severe. The flexibility of a high-speed four-cylinder engine approximates that of the "multi-cylinder" engine. The buying public is more familiar with the general construction of the four-cylinder engine than with that of the other types. The cost of repairs also is an important item; the fewer the number of parts that require overhaul, the better the owner should be pleased.

Engine Specifications

Now that the reasons for such an engine and its importance have been stated, we will outline some specifications. The engine should be of the four-cylinder type. As has been said, a high-speed engine should have as few moving parts as is possible; the having of fewer moving parts tends to make it more reliable. It also makes a short engine, which allows more body room and decreases the chances for torsional vibration in the crankshaft. The engine should have a displacement of about 165 cu. in. for a car with a wheelbase of approximately 118 in., a bore of say 3¼ in. and a stroke of 5 in. The valves should be located in the head, as this gives a more ideal combustion-chamber, and should be at least 1⅝ in. in the clear with a lift of at least ⅜ in.

The camshaft should be overhead and run in a bath of oil, but it should be arranged so that no large quantity of oil can get to the valves and cause trouble; otherwise the oil will be drawn in around the inlet-valve stem and have a tendency to foul the cylinders and cause a smoky engine at low throttle-positions. The drive of an overhead camshaft has been more or less a problem. A silent chain is out of the question and the ordinary bevel gear is too noisy, but it seems that the application of a helical bevel gear would solve this problem. The drive from the crankshaft should be taken through a pair of spur gears, to prevent the tendency of crowding because of any lateral motion of the crankshaft. From the spur gear, the drive should be through bevel gears and a vertical shaft to the camshaft, a suitable coupling being devised between the cylinder and the head to enable the head to be removed, the carbon deposit cleaned out and the valves ground, without disturbing the timing of the engine. We recommend an overhead camshaft because we believe that lifter-rods and rocker-arms are not practical for high-speed work. The inertia forces of the rocker-arms and lifter-rods run too high to be overcome by any reasonable amount of spring-pressure; it is difficult also to lubricate them properly. In addition, it is almost impossible to maintain proper adjustment, the engine becomes noisy and must be tampered with continually.

The crankshaft is of course a fundamentally important part of this engine. It should be counterbalanced. The crankpins and main bearings ought to be not less than 2⅛ in. in diameter, and there should be at least three main bearings. It is well to drill the crankpins hollow, reducing their weight and at the same time keeping the material at a point where it will do the most work.

The piston, wristpin and connecting-rod must be very light. The length of the connecting-rod should not be over twice the stroke. In the case of the engine described this would be 10 in. The reason for making these parts light is to reduce the load on the bearings as much as possible and to eliminate to a great extent the vibration caused by the differential speed of each pair of pistons as they pass the top and the bottom centers. This type of vibration becomes clearly evident at high engine speeds and cannot, of course, be overcome entirely in a four-cylinder engine.

The cylinders should be cast in block and surrounded with plenty of water, especially around the valves. At high speeds the heat becomes very great at these points; lack of water means distortion of the valve seats, which would cause a drop in power if the engine were run at wide-open throttle. When there is no room for a spark-plug in the top center of the combustion-chamber, we recommend the use of two spark-plugs, one in each side of the combustion-chamber; this gives excellent water circulation around the spark-plugs. We have found that,

[1]M. S. A. E.—President, Frontenac Motor Co., Indianapolis.
[2]Chief Engineer, Frontenac Motor Co., Indianapolis.

with engines having spark-plugs in each side, by cutting out the spark-plugs on one side there was a considerable drop in horsepower. Of course, this is more noticeable in engines of relatively large bore than with those having a small bore; but it has considerable effect on both, especially with the fuel mixtures we have to burn at present.

The lubrication of the engine should be a pressure-feed in all cases, and oil should be pumped through the engine in as large a quantity as possible. Provision should be made also for carrying a large quantity of oil in the engine; this will give the oil a chance to cool off before being pumped through the engine again. A compartment should be provided in the bottom of the crankcase where the oil will not be agitated, so that the carbon deposits and dirt can settle out. Clean oil adds materially to the life of the engine. We believe that before long engines will be fitted with small centrifugal oil-cleaners that can be removed, cleaned out and replaced without much trouble.

Carburetion on an engine of this type is another problem. To obtain efficiency at high speed the manifold must be large; it should be 1¾ to 1⅞ in. for an engine of the size which we are discussing. A manifold of this size will probably give trouble by loading-up at low engine speeds, and this would interfere with securing the good performance that people look for in an automobile. However, this trouble might be overcome by the use of a double manifold and carbureter, one large and one small, the latter to be used in taking care of speeds up to 25 m.p.h. and the former coming into play from there on. As most of the running of a car is done between 15 and 25 m.p.h. the small carbureter could be run practically wide-open all the time. This undoubtedly would give high economy and, owing to the high velocity of the gases, there would not be a tendency to load-up.

The inlet manifold should be carefully worked out to assure even distribution of the gases. With a large manifold and a large volume of gas at a high velocity there is a tendency for the gas to bank-up toward the two end cylinders. If this occurs, the two middle cylinders starve and immediately the exhaust valves of cylinders Nos. 2 and 3 become overheated and burn.

A high-speed engine should be equipped with a four-speed transmission driving direct on the third and geared-up on the fourth speed. On smooth level roads the fourth speed could be used, giving good touring speeds at moderate engine speeds and lengthening the life of the engine. The automobile should be built to a higher standard for the use of the high-speed engine. To be successful the manufacturer should work to a greater degree of precision and, as the working parts of the engine are all light and stressed fairly highly, this necessitates the use of high-grade materials properly heat-treated. Several attempts have been made in this country to produce high-speed engines, but for some reason they have not been very successful. However, there are a few small cars of this type that seem to give very good satisfaction, and we look for more developments along this line in the near future.

The Engine Described

Fig. 1 shows the high-speed racing engine designed by us, which won the 500-mile race on the Indianapolis Speedway in 1920. It is necessary in this type of high-speed engine to cut down the friction as much as possible. We attempted to do this in several ways. One is that the water-pump and the ignition system, which consists of a generator and a distributor and forms a unit with the water-pump, are placed in front of the engine and driven by what can be called the idler gears. The last named form part of the set of spur gears which drive the camshafts. Thus we eliminated several gears which usually run off to one side or the other to drive the water-pump and the ignition system. This makes a very clean, narrow and accessible engine.

This engine has two overhead camshafts in separate housings. The valve-actuating mechanism consists of a finger having a curved surface forming the section of a roller upon which the cam rides. This finger is to take the side-thrust. Between it and the valve-stem proper there is a straight piece of steel that might be called a tappet. This is the only means of adjustment and is ground to give the proper clearance. This makes a very light valve mechanism and needs very infrequent adjustment.

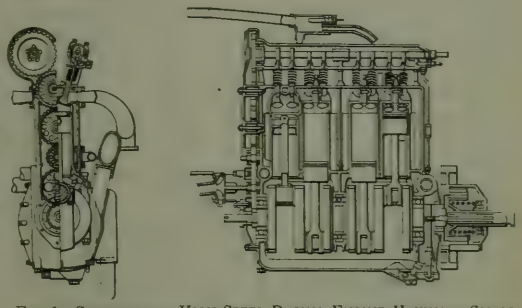


Fig. 1—Section of a High-Speed Racing Engine Having a Small Piston Displacement

As to the cooling of the pistons, it is not practical to use the method of heat dissipation through the wall of the piston to the cylinder wall and thence to the water in the jacket, because the wall area necessary in this case to conduct the heat from the pistons is so great as to make the pistons too heavy to travel at the required rate of speed. We have found that it is possible to air-cool these pistons, obviating the large wall area mentioned. This accounts for the unusually large breathers on the side of the engine, one in front and the other in the rear. The front one has a funnel-shaped top covered with a 16-mesh screen which prevents large particles from getting into the crankcase. The air goes in through this front breather-tube, through the crankcase and out through the rear breather, which has an inverted tube facing downward in a compartment separated from the crankcase proper, with a port entering the chamber at the top and also one at the bottom. The breather-tube in this chamber is sealed at the top and has a series of staggered holes down its side. It was designed to take as much air as possible from the crankcase and condense the oil vapor at the same time. The theory is that the air, due to the rotation of the crankshaft, passes in at the upper port and down and around the breather-tube. The oil vapor, settling on the wall surfaces, runs down and out through the lower port and back into the crankcase, while the air escapes through the holes in the wall of the tube and so on to the outside of the car. Of course, there is always more or less oil mixed with the air, and this is lost.

Two separate oiling systems are used on this engine; one mechanical and the other manual. The manual system is for emergencies; it is never used unless some-

FIG. 2—THE CYLINDER BLOCK AND THE LOWER HALF OF THE CRANKCASE WITHOUT THE SIDE PLATES AT THE LEFT AND AT THE RIGHT THE LOWER CRANKCASE WHICH CAN BE REMOVED WITHOUT DISTURBING THE CRANKSHAFT

thing gets out of order in the mechanical system. Both systems are what is known as the dry-sump type. The oil is carried in an 8-gal. tank on the car. There is a two-stage gear-pump which circulates the oil. The lower and smaller pump takes oil from the tank and pumps it through the engine; the upper and larger pump takes oil from the engine and pumps it back to the tank. There is a pipe running from the pressure-pump up the back of the engine and connecting with a pipe cast integrally with the cylinder block. Along the edge of the cylinder there are four plugs, which cover a small compartment from which jets project and deliver oil to rings mounted upon the crankshaft.

At the same point where the pipe enters the rear of the cylinder block there is a small pipe which conveys oil up to the camshaft. This pipe enters the rear end of one camshaft housing and is delivered by another pipe across to the other. The two rear camshaft-bearings each have a groove completely around their circumference and, by this groove and through a hole drilled in the camshaft, the oil is forced along the inside of the camshaft, which is drilled hollow. At the heel of each cam there is a 1/16-in. drilled hole, which supplies oil to each cam mechanism. The oil which escapes from the camshaft, after doing its work, is conveyed along the bottom of the housing to the front of the engine where there is a channel beneath the ball bearing which allows it to run out and down over the timing-gears. The oil that does not escape through the small holes in the heel of each cam passes out through the front of each camshaft and also down and over the timing gears. After the oil goes down through the timing-gear case it runs into the crankcase and along the bottom to a cone-shaped strainer located in the bottom of the crankcase. Through this strainer it is delivered to a compartment which forms a reservoir to allow dirt and carbon to settle out before being taken up by the scavenger pump. The rib along the bottom of the crankcase is not put there for strength, but to form a baffle-plate to prevent the oil from surging about in the crankcase and also to convey it to the scavenger pump.

On the opposite side of the cylinder from the pressure oiling system there is another pipe cast integrally with the cylinder and having two jets, one at either end and opposite the center cheeks of the crankshaft. The oil is taken from the tank by the hand pump at the outward stroke, delivered to these two jets at the inward stroke and projected against the center crankshaft cheeks. The hole drilled in the cheek picks up a quantity of oil every time it comes opposite the jet. This same pump delivers oil to the camshafts by way of the pipe leading from the back end of the camshaft housing to the pressure gage on the instrument board. The oil is pumped out of the crankcase and back to the reservoir tank by another hand pump.

The spark-plugs in this engine were made especially for the job. We used one spark-plug per cylinder, located in the center between the four valves, an ideal position. This necessitated an extra-long threaded portion, to get down into the combustion-chamber and still permit water to circulate around the valves. If we had tried to use the standard type of spark-plug, the opening needed would have been so large as to take all the water space.

The adoption of two dial thermometers was an important matter as they give accurate account of what goes on in the engine. One of these which is for water is located in the outlet water manifold. The other is for oil and is located in the lowest part of the crankcase. The oil thermometer is very valuable to the mechanician; the moment a part becomes overheated, from either lack of oil or insufficient clearance, the temperature of the oil rises and is indicated upon the dial of the thermometer. In such case the driver should drive immediately to the pits and inspect the engine for the trouble. On certain occasions when connecting-rods become heated rapidly and the mechanician was either inattentive or had not sufficient time to notify the driver, the connecting-rods have left the engine and been lost to view.

At the left of Fig. 2 the cylinder block and lower half of the crankcase without the side-plates are shown. The valves are in place and also the studs which carry the camshafts and their housing. This cylinder construction should be of interest as it is more or less of a departure from regular practice, inasmuch as the crankshaft is supported by the cylinder itself rather than the cylinder being supported by the crankcase. The crankcase in this case acts merely as an oil retainer. This has proved to be a very light, rigid and satisfactory type of construction. Both sides and the rear of the cylinder block are covered with a No. 16 gage aluminum plate, fastened on with No. 10-24 fillister-head cap-screws. The openings which these aluminum plates cover form very large core-prints, which has a tendency toward securing accurate castings. Castings which we have sectioned have shown that the walls, which run from 1/8 to 5/32 in. in thickness, did not vary. The cylinder block as shown weighs 125 lb. The illustration shows the two steel tubes which support the engine in the frame. By removing the plates on the side of the crankcase, the connecting-rod and piston can be taken out of the engine without disturbing the crankshaft.

The lower crankcase at the right of Fig. 2 can be removed without disturbing the crankshaft, as the center bearing is separate and forms a supporting member. The baffle-plate or rib, already mentioned, can be seen;

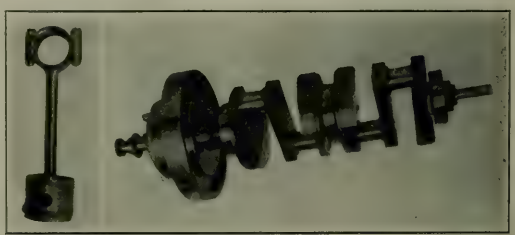


FIG. 3—THE CONNECTING-ROD AND PISTON AT THE LEFT AND THE CRANKSHAFT, FLYWHEEL AND CLUTCH AT THE RIGHT

FIG. 4—ONE OF THE CAMSHAFTS AT THE TOP WITH THE COMPLETE CAM HOUSING UNDERNEATH AND AN INTERIOR VIEW OF THE HOUSING WITH THE BRONZE CAPS FORMING CAMSHAFT BEARING AT THE BOTTOM

also the oil-pump and the spiral gear which drives the oil-pump at one-quarter engine speed. This gives the oil-pump a capacity of 1 gal. per min. We have kept the speed of all parts as low as possible to reduce friction losses in the engine.

The view at the left of Fig. 3 shows the connecting-rod and piston. The piston is 2½ in. long, 3⅛ in. in diameter and has two cast-iron rings, ⅛ in. square. The connecting-rod is made of chromium vanadium steel containing 0.35 per cent of carbon. The bearing is bronze, babbitt-lined. The connecting-rod has two bolts to hold the bearing cap; the pillar of the rod is drilled hollow and has a wall thickness of 1/16 in. The weight of the piston, with the wristpin and connecting-rod as shown, is 2 lb. 14 oz. The rod is 9 in. between centers. This is short for the amount of stroke, as in ordinary passenger-car practice a stroke such as we have here would call for not less than a 12-in. connecting-rod, but we find that we gain higher mean effective pressures with a short connecting-rod and also decrease the weight of the rod considerably. This connecting-rod has proved very satisfactory and never given trouble. The pistons are of aluminum and rough-machined, heated to about 700 deg. fahr. and then finished. This removes all internal stresses and they hold their shape under the high temperatures they attain in the engine.

The right section of Fig. 3 shows the crankshaft, flywheel and clutch. The crankshaft is very heavy, weighing 165 lb., and is counterbalanced. It might be advantageous to drill this shaft hollow and lighten it considerably, especially the crankpins. This would reduce also the weight of the counterbalances and thereby decrease the total weight of the shaft without lessening its strength much. The crankshaft is mounted on three ball bearings. It is made in two pieces and assembled in the center. It is locked rigidly by three hardened keys and can be taken apart and reassembled without disturbing its alignment. If we were building another crankshaft of this type we would make the center cheeks more nearly square and drill the center from end-to-end hollow, making it rigid and lighter at the same time. At the front end of the crankshaft the gear which transmits the power required to drive the camshafts is shown.

The upper view in Fig. 4 shows one of the camshafts. There are two plain bearings and one ball bearing in front which supports the timing-gear. Attention should be called to the heavy rim on the camshaft gear; this is for a flywheel effect. The camshafts run at sufficiently high speeds to store up considerable energy, which assists in opening the valves against the high spring-pressures we use. These are in the neighborhood of 125 lb. The cam has a lift of 7/16 in. The camshaft, drilled hollow as mentioned, has a wall thickness of ⅛ in.

The complete cam housing is illustrated in the middle portion of Fig. 4, while the bottom view shows the interior of this housing with the bronze caps forming the camshaft bearing and the fingers, which have been mentioned before, in place with their housing. By removing small screws the fingers can be removed in units of four, inspected, repaired if necessary and replaced in a very short time. The channel, which has been mentioned, is shown underneath the ball bearing, where the oil is allowed to run out at the front of the housing. The fingers do not have rollers but simply curved surfaces.

Fig. 5 presents two views of the timing-gear housing. That at the right is looking at the front of the housing, which is fastened to the forward end of the engine. The bottom hole is where the crankshaft projects through. The machined surface above it is for the water-pump and generator bracket. The shaft in the middle drives the water-pump. Above it is a toothed flange which is part of the generator coupling. The coupling at the generator has one tooth less. A rubber member which fits in between the flanges enables a micrometer adjustment to be made and the rubber center member provides a flexible joint that absorbs much of the shock present in timing-gears. The other side of the timing-gear housing is shown at the left of this illustration with the timing gears in place. These gears are made of chromium-vanadium 0.50 per cent carbon steel, heat-treated. The teeth are 12-pitch. The webs are drilled

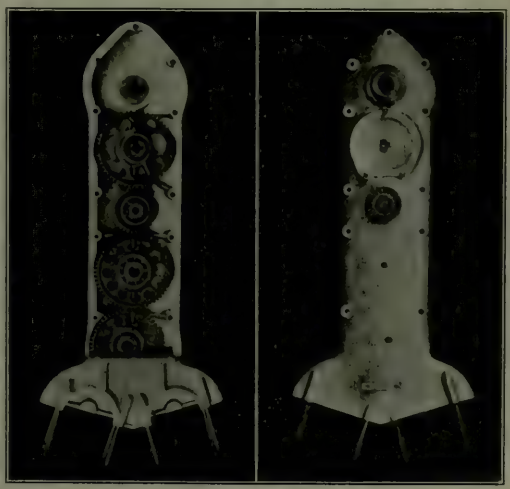


FIG. 5—TWO VIEWS OF THE TIMING-GEAR HOUSING

The View of the Left Shows the One Side of the Housing with the Gears in Place, While the View at the Right Is Looking Toward the Front of the Housing Which Is Fastened to the Forward End of the Engine.

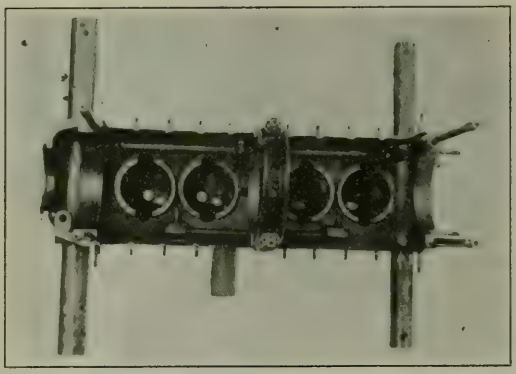


Fig. 6—Looking into the Cylinders from the Bottom

hollow for lightness and mounted on a single-row ball bearing. The ball bearings are held in the gear by simply turning over the edge of the gear against the chamfer on the outer race of the ball bearing. The lower gear drives the water-pump. The one directly above and meshing with this gear drives the generator. This gear is really smaller than it should be, as the engine was originally designed to take a magneto that had to run at crankshaft speed, which is much faster than is really necessary to run a low-voltage generator. It was determined after test to use the battery system of ignition in place of a magneto on account of the high engine speed, which is from 3400 to 3600 r.p.m.

Fig. 6 is the view seen when looking into the cylinders from the bottom. It shows clearly the oil-pipes already spoken of, the valves in place in the head of the cylinder and also the steel supporting tubes.

Fig. 7 is a close-up view of the oil-jet which supplies the oil to the oil-ring on the crankshaft. The oil leaving this jet is directed against the side of the oil-ring and carried by centrifugal force into a deep groove inside the ring and a hole connecting this groove with the connecting-rod bearing. The centrifugal force in this ring of oil exerts a pressure of about 40 lb. per sq. in. at the connecting-rod bearing. This system of oiling has its advantages and disadvantages, a very good feature being that the oil can be carried under high pressures to the connecting-rod without excessive pressures

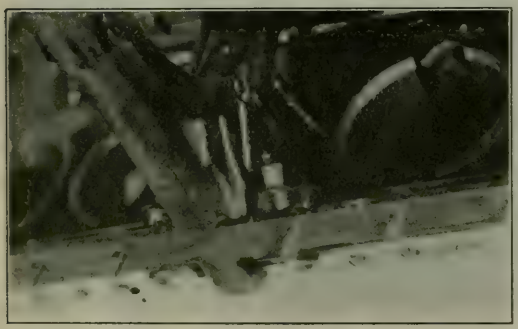


Fig. 7—The Oil Jet Which Supplies Lubricant to the Oil Ring on the Crankshaft

in the pipe lines which go to and from the engine. This does away with the danger of leakage through joints, as the pressure carried in the pipe lines need never exceed 5 lb. per sq. in. One disadvantage, however, is that the system is very sensitive to dirt and, if care is not taken to clean the jets and oil-rings, they will become clogged and cause bearing trouble. However, if the system is carefully watched, satisfactory results will be obtained.

Fig. 8 at the left shows the generator, distributor and water-pump unit, which is fastened into the forward end of the engine. This might have been executed in a more compact manner had it not been a replacement for magneto equipment. For the high speed at which this engine ran, battery ignition proved to be very successful. At no time during our season of racing have we had ignition trouble.

A view of the complete engine, with the magneto equipment as when the engine was first built, is presented in the right portion of Fig. 8. Attention is called to some experience we had with the distribution of gases. The manifold shown has an inside diameter of 2 in.; owing to its shape, we found that at high engine speeds the gases would travel toward the front and back of the engine; before cylinders Nos. 2 and 3 could take in a charge, it was necessary for the gas to bank-up in the end of the manifold and form its own passage to cylinders Nos. 2 and 3. This, of course, had a tendency to starve the two middle cylinders. A mixture suitable for the end cylinders would cause overheating of the two middle cylinders, resulting in the overheating of the valves. Not having time to experiment with manifolds, we substituted a small baffle-plate in the outer wall of the manifold, which served to deflect the gases toward the center. By a small amount of experimenting, which was merely cutting off the end of this baffle-plate and watching the exhaust, we were able to determine the proper setting. Unfortunately, this held good only at one certain speed; dropping below or going above that speed tended to reverse conditions and again cause trouble; but, as in our case the engine ran practically at a constant speed, we were able to use the manifold with fairly good results. We also tried the use of two carbureters with separate manifolds, but this was not at all satisfactory. The velocity of the gases was so great that when the valves closed there was a plus pressure against the back of the valves which resulted in a blow-back through the carbureter. To correct this we tried a by-pass from one manifold to another to allow the plus pressure to be conveyed to the other manifold, but this did not prove successful.

The valves in this engine have a diameter of 1 7/16 in. in the clear, and a lift of 7/16 in. The area of opening for one valve is 1.70 sq. in.; the total valve area is 6.81 sq. in. The engine, on the dynamometer, delivered 86 hp. at 3200 r.p.m. This is not as high as has been reported from tests of eight-cylinder engines of the same piston displacement. On a test under a wide-open throttle this engine, running at 3200 r.p.m., delivered an average of 78 hp. for 1 hr. The result might have been better had the air in the test-room not been contaminated with exhaust gases, causing a considerable drop in the horsepower. We found that when starting up with a clear room the engine would pull very well; as the room became filled with burnt gases the beam of the dynamometer scale would begin to drop. During this 1-hr. run the engine had a gasoline consumption of 0.625 lb. per hp-hr. This same engine ran 500 miles on the Indianapolis speedway at an average speed of 88.7 m.p.h., with an

FIG. 8—THE GENERATOR, DISTRIBUTOR AND WATER-PUMP UNIT WHICH IS FASTENED INTO THE FORWARD END OF THE ENGINE AT THE LEFT AND AT THE RIGHT A VIEW OF THE COMPLETE ENGINE AS IT WAS FIRST BUILT WITH THE MAGNETO EQUIPMENT

average of 10 miles per gal. of gasoline for the whole race.

The water manifold, with a small pipe which leads to the thermometer, and the breather pipes, front and rear, are shown. It can also be seen how the covers come completely off the side of the crankcase. This opens up the whole side of the engine, making it very accessible besides being very light in weight. The whole engine, with exhaust manifold complete, weighs 410 lb.; a large part of this weight is, of course, in the crankshaft, which weighs 165 lb.

THE DISCUSSION

A MEMBER:—At what engine speed was maximum horsepower obtained?

C. W. VAN RANST:—At maximum horsepower on the block the engine speed was 3200 r.p.m. On the track we continued up to 3500 and 3600 r.p.m.

MAX H. THOMS:—What is the axle ratio?

MR. VAN RANST:—It is 3 to 1.

MR. THOMS:—What sizes of tire were used?

MR. VAN RANST:—Three cars, the winner among them, used 32 x 4 in. front and 32 x 4½ in. rear tires. The others used 32 x 4½ in. front and 33 x 5 in. rear tires.

MR. THOMS:—What is the material in the flywheel and the diameter of the flywheel?

MR. VAN RANST:—The material is plain carbon steel; the flywheel diameter is 13 in.

A MEMBER:—Please describe the breather system, from the radiator to the crankcase.

MR. VAN RANST:—The air comes through the radiator and there is enough draft to force it through the crankcase. The ideal condition would be to take it from outside, but the air comes through the radiator so fast that it does not heat up to a high degree and so it makes no difference.

A MEMBER:—Do you have trouble with accumulations of dirt in the oil?

MR. VAN RANST:—The greatest trouble in taking air into the crankcase is with dirt; it is serious and a thing we would like to get away from. We have to give the crankcase air or it will become too hot. There are means, I suppose, whereby we could get a less amount of dirt. I think it important to give all the air possible. That is one reason I mentioned that the crankcase should be fitted with a compartment where the dirt and carbon can filter out of the oil and not be carried through the engine.

GEORGE A. WEIDELY:—You obtained 10 miles per gal. of gasoline; how many miles did you obtain per gallon of oil?

MR. VAN RANST:—We prefer not to state that figure because this type of engine is not economical with oil. Due to the arrangement of the camshaft and because the valve mechanism is open, much oil is lost. The racing-car engine, unfortunately, seems to slobber a lot of oil, anyway; especially in this type, where the breather is large and the cam housing is overhead. The oil consumption was very high.

CHESTER S. RICKER:—What kind of oil was used?

MR. VAN RANST:—Straight castor oil. We tried mineral oil but found that the carbon deposit was too great and caused us to burn out three connecting-rods. After we used castor oil we never burned out a rod. The other oil would become foul and the jets would clog; immediately a rod would burn. With castor oil there was very little carbon and the oil had greater body. The temperature of the oil runs anywhere from 220 to 250 deg. fahr.

A MEMBER:—Do the fingers on the cams take all the thrust of the cams?

MR. VAN RANST:—Yes.

MR. THOMS:—What tappet clearances are there on the exhaust and inlet valves?

MR. VAN RANST:—The exhaust has 0.030 in. and the inlet 0.025 in. clearance.

A. L. NELSON:—In regard to experiments with fuels and compression ratios, what was done?

MR. VAN RANST:—We carried on a few experiments. Recently we tried a "dope" which Mr. Kettering prepared to retard the speed of combustion and prevent detonation. We found that in this type of engine it proved to be of no advantage. We experimented with compressions up to 135 lb., varying the percentage of dope to gasoline from 3 to 3½ per cent; but we lost power as compared to regular practice. The compression ratio that we found to be best was 5 to 1, which gave about 105 lb. per sq. in. gage compression.

A MEMBER:—What is the comparison of an engine of the type described with the standard type, as far as quietness is concerned?

MR. VAN RANST:—At ordinary traveling speed there is no reason it should not be as quiet as the average engine of to-day. I believe it would be more quiet than engines with the rocker-arm and lifter-rod valve actuation used in the cheaper classes of car. Also, at higher speeds I believe it would be more quiet; but there would be less tendency for the valves to flutter, due to the elimination of rocker-arms and lifter-rods, although at higher speeds there is a considerable hum anyway. I believe the noise would not be detrimental. I know of no engine that I would call quiet when running at high speed.

DANIEL C. TEETOR:—Is there anything special in regard to the design of the piston-rings?

MR. VAN RANST:—No; they are of cast iron, cast separately and machined to be ⅛ in. wide and ⅛ in. deep; two rings are used, with just an ordinary 60-deg. slot.

A MEMBER:—How much clearance is there beneath the rings?

MR. VAN RANST:—The clearance is 0.010 in. overall; that is, 0.005 in. on each side.

A MEMBER:—What material is used for the timing-gears?

MR. VAN RANST:—They are of chromium vanadium steel containing 0.50 per cent of carbon and heat-treated.

A MEMBER:—How are the timing-gears kept quiet?

MR. VAN RANST:—We do not attempt to keep them quiet; they hum considerably when running. They could not be made quiet, because the webs are drilled, this tending to make them noisy.

A MEMBER:—How could that be corrected in a commercial car?

MR. VAN RANST:—I would recommend the use of helical bevel gears, having them drive a vertical shaft to the overhead camshaft.

ARTHUR HOLMES:—In what manner are the wristpins lubricated?

MR. VAN RANST:—By splash. Two small holes are drilled in the top of the wristpin boss and there are grooves the full length of the bearing inside. The oil coming from the connecting-rods is thrown upward into the cylinder and is picked up by these holes. Oil is also picked up from the cylinder wall by the wristpin hole.

LON R. SMITH:—What is the size of the crankshaft?

MR. VAN RANST:—The crankpin is 2⅛ in. in diameter. The main bearings are ball bearings 2¼ in. long and are very large.

A MEMBER:—Do you use shims in the connecting-rods?

MR. VAN RANST:—There are no shims and no grooves. We could not use shims, as this would cause a slot the entire length of the bearing which would allow the oil to pass through, because it is under such high pressure, and would probably cause a smoky engine. We have to keep the bearing as tight as possible, aside from the necessary clearance.

A MEMBER:—What is the pressure of the oil at the connecting-rods?

MR. VAN RANST:—It is calculated to be 40 lb. per sq. in.

A MEMBER:—Did you have any difficulty with the babbitt separating from the bronze bearings?

MR. VAN RANST:—There were only two or three instances that I know of where the babbitt became loosened from the bronze.

MR. WEIDELY:—Those who have interested themselves in racing or other contests are familiar with the fact that many such events have been won by road ability rather than because of engine output; on the other hand, faults of the present-day motor-car often are found in parts other than the powerplants.

The limiting of displacement in our more important races has supplied an incentive to develop engines having abnormal torque at an abnormal compression and a still more abnormal speed, which has resulted in research along the line of engine improvement to the exclusion and detriment of improvement in other almost equally important parts of the car. It is doubtful whether the results gained in racing events help to improve the commercial article as much as they might and would if rules and conditions were added covering fuel and oil consumption, power losses, tire wear, acceleration, ability and durability of brakes and other things looked for in the modern car.

In view of the fact that probably all present-day cars, racing or otherwise, show a power loss at the wheels of over 20 per cent exclusive of slip, there seems to be food for thought in a direction other than toward the engine. It is true that these matters might detract from the sporting side of a contest, but the results from such events would, no doubt, pay in a big way if these matters were considered. I have just learned that the part of the rules covering the bench and dynamometer tests of all cars entered in the Grand Prix Race, in France, has been dropped. This is really a misfortune for the industry as a whole, as otherwise no doubt much useful information could have been gained.

MR. RICKER:—There was recently a very interesting contest in France in which the fuel consumption was the criterion rather than the engine displacement. The question of a bench test for the French Grand Prix Race was largely, I understand, a matter of not desiring to put an engine to that test before it had to go into the race. A race is a question of a complete chassis rather than one of the engine alone. On a bench test the engine might break down or a good engine that did not fulfill the exact conditions might be eliminated; yet the engine and the chassis in which it was installed might make an ensemble that would win the race. Some of the suggestions that Mr. Weidely makes might well be considered by automotive engineers and especially by the automobile contest organizations of this country.

GRAPHITE LUBRICANTS

IT is obvious that to try to use graphite as a lubricant instead of oil would be useless, as solid friction is always greater than liquid friction. The oil used must be able to keep the metallic surfaces apart, either by its oiliness, its power of creeping with an unbroken film over the metal, which necessitates a low surface tension, or by its viscosity, whereby it is carried along by the rotating portions, and wedged in between them and the fixed portions. To use an oil of a viscosity more than sufficient to do this is wasteful, as energy is lost in shearing oil. Liquid lubricants, however, are greatly influenced by a rise of temperature, and a decrease in the viscosity of about 3 per cent per degree centigrade is quite a usual value for thick oils between 60 and 90 deg. cent. At cylinder temperatures all oils have very much the same viscosity. Under such severe conditions liquid oil films are apt to break, so the presence of a solid lubricant like graphite, which is almost entirely unaffected by such temperatures, is highly desirable. Graphite, then, may be considered as a lubricant of special value for cylinders and valves of internal-combustion engines. It is also of value for use on bearings, especially when subjected to heavy pressure, in which case the oil film may fail. A graphite film in a bearing, besides reducing the solid friction of metal to metal, provides a skin which is renewed from the oil, this skin being worn away instead of the metal. After graphite has been in use in an engine for some time the amount in the oil, always a very small quantity, can be further reduced, for once the graphite surface is formed a very small quantity suffices to maintain it. It is difficult to explain why the use of graphite reduces the consumption of lubricating oil, but it undoubtedly does so. The film deposited is too thin sensibly to alter the clearances. The explanation which appears the most probable is that by reducing the friction and the eddy currents in the oil due to surface irregularities, the temperature of the oil film is, on an average, reduced, and its viscosity being on that account greater, its rate of flow is diminished. It is also possible that, on the cylinder walls, where oil probably vaporizes with the fuel, a certain residue of graphite remains, and in this case the clearances between piston rings and cylinder walls may be slightly reduced. Apart, however, from any explanation of its action, the saving is an established fact, and in certain cases it appears that power also is saved.—W. R. G. Atkins in *Automobile Engineer*.

Recent Development of Artillery Automotive Material

By Capt. J. B. Haney[1], U. S. A.

Chicago Truck and Tractor Meeting Paper — *Illustrated with* Photographs

LAST year at the Chicago Truck and Tractor Meeting George W. Dunham read a paper entitled Artillery Motorization as Related to Caterpillar Traction[2], in which the problem of artillery motorization and the achievements in that line up to the end of 1919

Fig. 1—Experimental Tractor Hand Cart with a Load of 310 Lb. Being Pulled Over Soft Wet Ground by One Man

were presented in a clear and convincing manner. In this paper I will undertake to describe briefly the progress of the work of artillery motorization in the past year. Mr. Dunham referred to the Westervelt Board, appointed by the War Department to make a study of the armament, calibre and types of material, kinds and proportion of ammunition, and methods of transport of the artillery to be assigned to a field army. This Board made a very complete report based on the experiences of the Allied Armies during the war, and its recommendations will be the basis of armament development for some time to come. Without going into detail it will be sufficient to note that the development of the following track-laying material is directly recommended by the report of this Board:

Tractor hand-cart
Reconnaissance tractor
Division artillery tractor
Corps artillery tractor
Army artillery tractor
Heavy or 15-ton artillery tractor
Tractor caissons of 1½ and 3 tons capacity
Trailer caissons of 1½ and 3 tons capacity
Self-propelled mounts for the division, corps and army gun and howitzer.

The Board also recommended investigation of the use of wheeled trailers on which the track-laying material could be loaded and towed over good roads by trucks, and of the possibility of incorporating trailer wheels in the track-laying vehicles themselves.

The various types of material constructed in the past year will be taken up in the order given. The first of these is the tractor hand-cart recommended by the Westervelt Board in approximately the following terms:

> A cart with caterpillar tracks to be pushed or drawn by one or two men, to be used as an ammunition carrier in stabilized warfare, or for carrying other miscellaneous supplies, which due to local conditions would otherwise have to be carried by men on foot.

A suitable mechanism for applying power direct to the track, which would enable the cart to be worked over steep grades or terrain over which two men could not draw or push it was also to be provided. Specifications were drawn up for this tractor hand-cart and bids or designs asked for, but no bids being obtained the design work was assigned to the engineering offices of the Tank Tractor and Trailer Division of the Ordnance Department. In the absence of any data on track-laying vehicles of this type an experimental model, shown in Fig. 1, was constructed rather for the information of the designer than with the idea of producing a vehicle for test by the Ordnance Department or the service. It is 36 in. long and 24 in. wide overall. The load capacity is 200 lb. The body is watertight and of sufficient displacement to float the cart with a full load, as can be seen by referring to Fig. 2. The estimated weight of a cart of this type was 125 lb., but the weight of this preliminary model is somewhat greater. The design shown here has a pulley and ratchet mechanism, by which power can be applied to the tracks in accordance with the specifications. This model proved successful in the various tests and demonstrations to which was subjected, but it has been decided that the limited service a cart of this type can give will not justify its development at this time.

The ¼-ton or reconnaissance tractor shown in Fig. 3 is intended to fill the gap in motorized artillery left by the horse of the individual mounted man, as it is not practicable to combine horse and motor transport in the

Fig. 2—Experimental Tractor Hand Cart Floating with a Load of 360 Lb.

[1] Ordnance Department, Washington.
[2] See The Journal, March, 1920, p. 161.

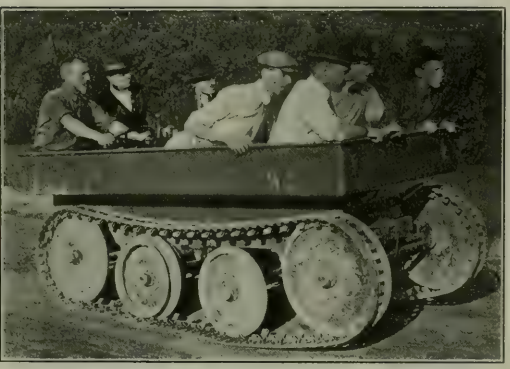


FIG. 3—EXPERIMENTAL RECONNAISANCE TRACTOR

same unit. The motorcycle has been tried for the transport of officers, scouts, signal men, etc., but as it requires fairly good roads; its use is limited. The recommendations of the Westervelt Board were for a reconnaissance tractor weighing 1200 lb. with a load capacity of 500 lb. and a maximum speed of 15 m.p.h., but both types of vehicle produced have exceeded this weight limit considerably. As can be seen from Fig. 4, this tractor will operate in water of considerable depth. Its body has sufficient displacement to float the tractor with its load, while its weight is such that it can cross on improvised bridges, trenches or ditches too wide for it to cantilever. Power is furnished by a Militor motorcycle engine fitted with a Sirocco fan to supply air for cooling. The specified high speed is 15 m.p.h., but rates in excess of this have been maintained for short periods.

The striking feature of this tractor is the track invented by Lieut.-Col. A. M. Chase, who is now in charge of the Syracuse Engineering Office of the Tank, Tractor and Trailer Division of the Ordnance Department. This track has been used also on tractor carts designed by Colonel Chase. It will, it is thought, make possible the construction of small vehicles of the types just described without exceeding reasonable weight. This track consists of two fiber strips connected at intervals by arch-shaped metal pieces which bear on the rubber-tired wheels. Steps are being taken to subject this type of track to a test that will determine its durability.

A second model of the reconnaissance tractor is shown in Fig. 5. This has not yet been given a test or demonstration, so there are no data as to its performance. It has a water-cooled engine and a metal track. A similar model is being built, but with an air-cooled engine and a combined fiber and metal track. When the second model is completed, tests will be made to determine the ability of this type to fulfill the requirements of the Westervelt Board.

[2] See THE JOURNAL, October, 1920, p. 321.

FIG. 4—RECONNAISANCE TRACTOR WITH LOAD IN DEEP WATER

HEAVY TRACTORS

Next is the Division or 2½-ton tractor. Its name indicates the ideal weight of the size of vehicle wanted but so far this has not been realized. The first Division tractors were built in 1918 but were finished too late to be of service during the war. Before putting them into service the Ordnance Department found it necessary to make rather extensive modifications to eliminate certain

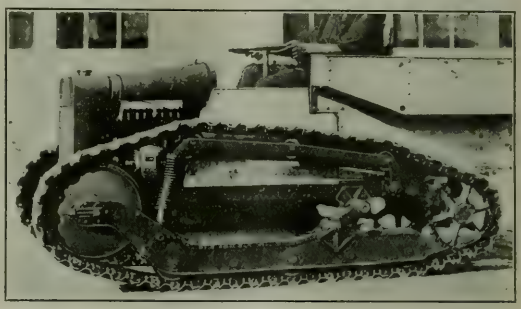


FIG 5—ANOTHER TYPE OF EXPERIMENTAL RECONNAISANCE TRACTOR

defects, so none of these tractors actually went into service until 1920. As now constructed the tractor weighs 7700 lb. It has speeds ranging from 5 to 9 m.p.h. at normal engine speed but a rate as high as 12 m.p.h. has been maintained for short periods. This tractor which is illustrated in Fig. 6 is still regarded as an experimental type but several organizations have been equipped with them with a view to obtaining more definite information as to the tactical requirements of high-speed tractors for Division Artillery materiel.

A tractor or other track-laying vehicle intended for use in the theatre of operation of an army requires sufficient power available at the tracks to move it and its load over the terrain likely to be found there. It will be required to cross trenches, to climb into and out of shell holes, travel through mud-swamps and cross streams of considerable depth. This mobility is best secured by a very low track speed with the engine developing its maximum torque. On the other hand, the tractor must be capable of sustaining the same or greater speed than a truck train when operating on good roads, assumed as 12 m.p.h. In case of rapid concentration of troops or surprise attacks, when the troops are moved in trucks, the artillery must accompany them and be ready to go into action with the infantry; otherwise valuable time would be lost.

The Ordnance Department designed and built the Division Artillery tractor model of 1920 shown in Fig. 7 in which the defects of the earlier models were avoided and the requirements for higher speed were successfully met. This tractor was exhibited at the Summer Meeting of the Society at Ottawa Beach, Mich., in June, 1920, and a very complete description by the designers, G. R. Pennington and S. K. Wellman, was published in THE JOURNAL for October 1920,[3] under the title the New Army

Light Artillery Tractor. It has speeds ranging from 1 to 15 m.p.h. with the engine running at normal speed, and by speeding up the engine it has attained 18 m.p.h. Every effort has been made to build this tractor to operate with the least practicable noise, rubber-cored track rollers being used. It is waterproofed to operate successfully in water 4½ ft. deep at a speed of 7 m.p.h. While the track-supporting system operates satisfactorily, to offset the effects of loading the track, it has been found that it absorbs considerable power; experiments are under way in this connection. The formal test which the tractor is now undergoing will give sufficient data to determine whether the system mentioned will be retained.

Supply and Maintenance

With respect to supply and maintenance the ideal Artillery tractor would be one produced in quantity for commercial uses. Unfortunately, however, three factors on which the Army places considerable stress, speed, waterproofing and quiet operation, do not as yet enter decisively into the design of commercial tractors. If commercial tractors fulfilling all the requirements of the Army are not obtainable, the next best thing is to find one that with the fewest modifications will meet them approximately. We have not found such an one, but one is being developed that seems very promising. Its development belongs to the current year, however, and not to 1920.

Unless an emergency should arise in the near future, it is intended not to build any more 5 and 10-ton tractors of the type now in use, but to develop a new tractor of a size between those of the Division tractor described above and the 15-ton tractor now under construction by the Ordnance Department to carry out the recommendations of the Westervelt Board, the latter tractor will be completed during the present year.

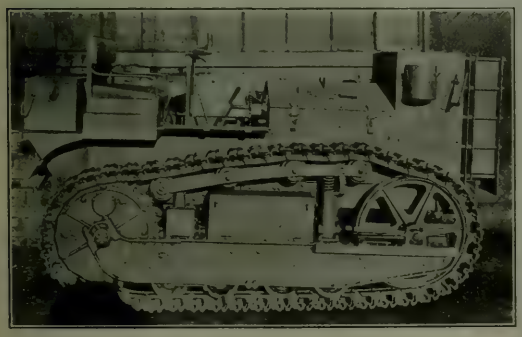


Fig. 6—Division Artillery Tractor

But little can be said in reference to tractor caissons. The types, both domestic and foreign, built during the war, were of too great weight to operate economically. So far nothing to replace them has been developed. Trailer caissons of ¾, 1½ and 3-ton capacity, the two last named recommended by the Westervelt Board, are under construction, but so far but one, a 1½ ton trailer, shown in Fig. 8, in which the track mechanism of the model 1920 tractor is used, has been offered for test. The absence of the track-supporting mechanism so evident in the tractor should be noticed.

The track-laying trailer problem is a rather difficult one. The question whether the body shall be supported at two points like a two-wheeled cart or at three or four points is unsettled. Sharp turns are made with difficulty as indicated by the many broken drawbars. A decision as to the most satisfactory design can be reached only after thorough tests of different types.

Fig. 7—Two and One-Half-Ton Division Artillery Tractor Designed by Ordnance Department Climbing

Gun-Mounts

In the opening paragraphs of this paper reference was made to the recommendations of the Westervelt Board that wheeled trailers should be supplied, or trailer wheels incorporated in track-laying vehicles, in order that they might be towed at high speed, on good roads, by trucks. We have two types which obviate this requirement, the combined wheeled and track-laying and the high-speed track-laying vehicles. The first is exemplified by the Christie type, the second by the Division artillery tractor and the 75-mm. self-propelled gun-mount. The use of a separate wheeled trailer is no longer considered for moving tractors and self-propelled gun-mounts over good roads at high speeds.

The self-propelled gun-mount shown in Fig. 9 is a Holt caterpillar. The track rollers have rubber cores and are rubber-tired, the driving sprocket and idler are rubber-tired and the track has rubber pads inserted in each

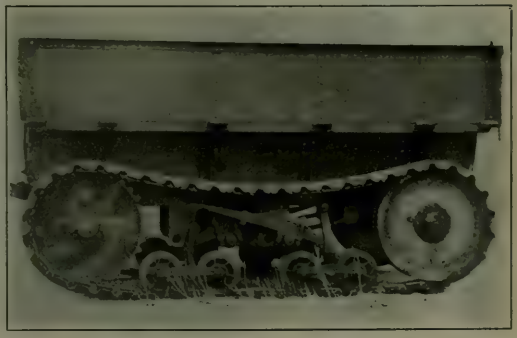


Fig. 8—One and One-Half-Ton Trailer

Fig. 9—Self-Propelled Mount for 75-Mm. Gun Climbing a Bank

shoe. According to the builder this track has shown surprising durability; after 600 miles' travel it shows slight wear, and it is thought that it will outwear an all-steel track. We are told that this mount can sustain speeds up to 25 m.p.h. on good roads and makes no more noise when running at this speed than a heavy solid-tired truck. It has all the climbing and maneuvering ability of the tractor and will go, it is stated, anywhere its driver has nerve to take it.

The combined wheel and track-laying Christie-type mount for the 155-mm. gun has shown that it possesses merits to justify its issue to the artillery for a service test. One of these mounts was exhibited at the Summer Meeting of the Society at Ottawa Beach, Mich., in 1920. A view showing the mount crossing a sharp ridge or bank, in which the action of the track and track-supporting wheels are clearly brought out, is given in Fig. 10. The latest design of this mount weighs 38,500 lb. complete with the gun, the overall length including the gun is 236 in. and the width is 112 in. The 120-hp. engine gives speeds ranging from 1½ to 15 m.p.h., the latter on wheels, the maximum speed on tracks being somewhat lower. Fifteen miles per hour can be exceeded

Fig. 11—Gasoline Electric Self-Propelled Mount for 240-Mm. Howitzer

under favorable road conditions by speeding up the engine.

This combined wheel and track-laying type of vehicle, while not considered as the ultimate, is a most interesting development, but its abilities have not been so rigorously tested as those of the tracklayer. When it is operated as a wheeled vehicle, it is steered by the front wheels, like a truck; as there is no differential, care must be taken in making short turns to release the clutch controlling the inner driving-wheel. The tracks can be taken off or put on in a very short time by a trained crew. When not in use they are carried on the track-supporting shelves on either side of the mount. Mechanism is provided for raising and lowering the center wheels of the mount. These are raised free of the ground when traveling as a wheeled vehicle, but lowered to take a large part of the load when operating on its tracks. When the track is in use the steering-knuckles are securely locked and the mount steered by the clutches and transmission in the usual manner.

In addition to this 155-mm. mount there are being built mounts of a similar type for Division and anti-

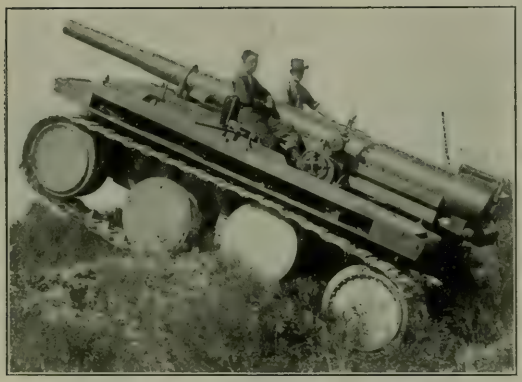


Fig. 10—Combined Wheel and Track-Laying Mount for 155-Mm. Gun

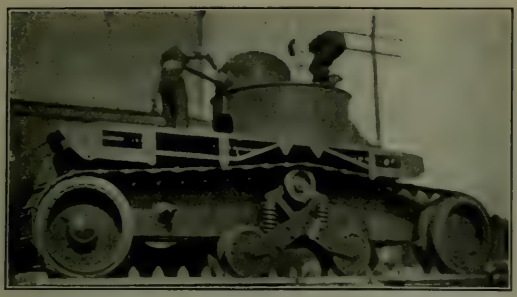


FIG. 12—COMBINED WHEEL AND TRACK-LAYING TYPE OF TANK

aircraft guns. The Ordnance Department has two types of self-propelled mount for the 240-mm. howitzer in which the powerplant and the mount are on a single vehicle. The weight of these vehicles, 106,000 lb., is so great that their use is limited. It is doubtful whether this line of development will be continued.

There is a third type of mount for the 240-mm. howitzer which has advantages that may justify further development. This is the gasoline-electric type, consisting of two vehicles illustrated in Fig. 11. The first carries the 150-hp. engine and generator and a supply of ammunition; the second is the gun-mount. Each unit has two 70-hp. electric motors, one for each track. When traveling on ordinary roads the two vehicles are coupled by a drawbar and connected by an electric cable. The second vehicle can be towed by the first or the motors of both vehicles used, as required by road conditions. If the going is so difficult that the power available will not suffice for both vehicles, they can be moved one at a time. Either vehicle can maneuver separately in bad going or when being placed in firing position. About 200 yd. of cable is carried for this purpose. While this system of electric transmission has not been as thoroughly tested as the mechanical transmission, it offers a satisfactory solution for heavy self-propelled mounts.

TANKS

At the close of the great war the United States found itself with a small number of British tanks of various models, several hundred Renault 6-ton tanks of both American and French manufacture and 100 partially completed Mark VIII tanks. These last, weighing about 40 tons each, have been completed during the past year. They were designed primarily for crossing the extensive trenches of the Hindenberg line and while they did not get a chance to show what they could actually do, tests indicate that they are very successful. The pilot Mark VIII tank has a record of over 200 miles at an average speed of about 4½ m.p.h. without extensive repairs and with, the possible exception of spark-plugs, relatively few replacements.

Tank warfare is so new that its demands have not crystallized, but the present tendency is toward a smaller tank than the Mark VIII but larger than the 6-ton Renault. Two such types are being produced. One, the combined wheel and track-laying Christie type by the Front-Drive Motor Co. of Hoboken, N. J., is shown in Fig. 12. This tank is about 22 ft. long overall, weighs about 16 tons and is equipped with a 120-hp. engine. It is expected to give a speed of 15 m.p.h. at normal engine speed, when traveling on wheels, on good roads. The large center wheels of the 155-mm. gunmount have been replaced by track-rollers, which resemble in principle at least those of the Ordnance Department's 2½-ton artillery tractor model 1920. As originally laid down this tank had but one center wheel on each side, in place of the two used in the 155-mm. self-propelled gun-mounts.

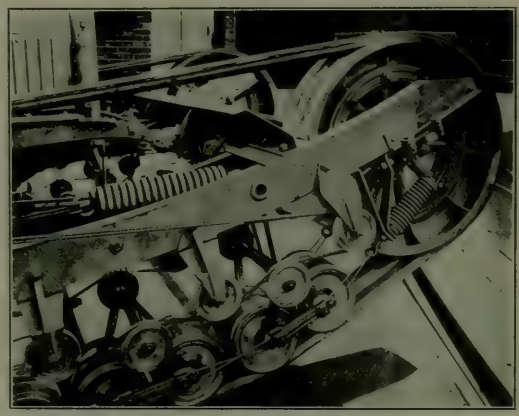


FIG. 14—DETAILS OF THE CABLE SUSPENSION TRACK

This single wheel did not function in a satisfactory manner in the early trials and was replaced by the construction shown. These track-rollers are connected with the transmission so they can be raised or lowered by the driver with no more effort than depressing a pedal. This arrangement is to facilitate easing over sharp crests. It has performed some interesting stunts but has not been subjected to a formal test.

The Ordnance Department is designing and building two medium-sized tanks, one with a track of conventional design and the other with a cable-suspension track. The latter is the invention of Major Johnson, an officer of the British tank corps, and if rumors are to be believed British tanks equipped with tracks of this type are being run at speeds as high as 30 m.p.h. The Ordnance Department has at Aberdeen Proving Ground a White staff car equipped with a fabric track and cable suspension built in England from Major Johnson's design. Some idea of this form of suspension can be obtained from Fig. 13. This particular vehicle has not proved a success so far but it is believed that with a few changes and adjustments it can be operated successfully as an experimental vehicle. The close-up of the front end of the White car in Fig. 14 shows the details plainly.

FIG. 13—STAFF CAR WITH CABLE SUSPENSION TRACK

ACTIVITIES OF THE SECTIONS

Sections Calendar

BOSTON
April 22—Storage Batteries. F. J. Stone. Head Lights.
May —Meeting in Worcester, including plant inspection trip.

BUFFALO
April 19—Carbureter Performance. F. C. Mock.

CLEVELAND
April 15—Aluminum in Engine Construction. Lawrence Pomeroy.
May 20

DAYTON
May 17

DETROIT
April 22

METROPOLITAN
April 14—Low-Grade Fuel Carburetion. R. H. Beach.

MID-WEST
April 11—Automatic Charging of Batteries. H. M. Beck.

MINNEAPOLIS
April 6—Repair Equipment.

WASHINGTON
April 1—Aeronautic Meeting. Brigadier-General Wm. Mitchell, Major H. W. Harms.

ALL of the Sections will elect officers for their next administrative year at the meetings this month. The Sections delegates to the annual Nominating Committee of the Society will also be selected at the April meetings. The Nominating Committee is composed of one representative elected by each Section, together with three members from the Society at large elected at the Summer Meeting. This Committee is then immediately organized and proceeds with the selection of nominees for the Society offices next falling vacant, culminating in the election of officers for 1922.

Since the Sections have so large a part in the selection of Society officers through the working of this Committee, it is very desirable that the delegates chosen should be men thoroughly conversant with the policies of the Society, and familiar with the records of men who may be proposed as candidates for office.

RECENT MEETINGS.

Good Roads and Equipment was the subject presented by C. O. Wold at the Minneapolis Sections meeting held on March 2. The Mid-West Section at its meeting on March 11 listened to a paper on Valve Actions and Engine Design by Chester S. Ricker and John Moore. H. G. Farwell talked on Brakes before the Metropolitan Section on March 16. He had returned from Europe shortly theretofore, and reported the observations he had made there with regard to current practices connected with his professional contribution to the members. A moving picture was shown during the evening which was particularly interesting to all those who have had to deal with the problem of industrial relations. This film gave the history of the Bantam Ball Bearing Co., which has been one of the pioneer companies in working out a system of cooperative management with its employees. J. S. Marvin, assistant general manager of the National Automobile Chamber of Commerce, in an after-dinner address outlined the present activities of that organization.

Economic Automotive Design was the subject of one of the papers given before the Washington Section on March 18. This paper was presented by B. B. Bachman, chairman of the Standards Committee, and the vice-president of the Society for Motor-Car Engineering. At the same meeting Economic Highway Design and Maintenance was discussed by H. G. Shirley, secretary of the Federal Highway Council and formerly chief engineer of the Maryland Highway Commission.

The Pennsylvania Section joined with the Engineers Club of Philadelphia in holding on March 22 a meeting at which Richard Spillaine of the Financial Department of the Philadelphia *Public Ledger* spoke on How the Engineer Can Best Capitalize Himself.

A comprehensive session on Post-War Progress in Aviation was held at Dayton on March 22 by the Section of the Society just established there. G. M. Williams, general manager of the Dayton-Wright Airplane Co., spoke on the actual accomplishments in commercial aviation since the armistice. Having returned recently from Europe, where he inspected many commercial airplane lines in operation, he was able to make an interesting comparison between European and American progress. C. F. Taylor, engineer in charge of the Powerplant Laboratory at McCook Field, covered the developments in powerplants and fuels that have made possible flights at great altitudes, increase in compression ratios and greater engine size and efficiency. F. W. Caldwell, of the propeller branch of the Air Service, spoke of the improvements made in his field of engineering endeavor, including reversible propellers and the use of steel in the manufacture of propellers. Lieut. C. N. Monteith, chief of the Airplane Section, gave a résumé of the newer phases of airplane construction, such as all-metal planes, internally-braced planes and high-speed aircraft.

The Cleveland Section held a dinner and technical meeting on March 18.

During the Automobile Show at Boston the progressive Section of the Society established there held a meeting on March 17. George M. Graham, vice-president of the Pierce-Arrow Motor Car Co., gave an illuminating talk on The Business Situation.

The Relation Between the Automotive Industry and Department of Engineering Research at the University of Michigan was the subject Prof. A. E. White treated at the meeting of the Detroit Section held on March 25. This is a matter of peculiar interest at this time because of the prospective increased activity of the Society in research matters.

SOME EXPERIMENTS ON THICK WINGS WITH FLAPS

IN the paper by C. D. Hanscom entitled Some Experiments on Thick Wings with Flaps which was published in the March issue of THE JOURNAL an error was made in connection with the characteristic curves of the H1, H3a, H3b wing sections which appear on pages 271 and 272. In all four sets of curves the ordinates at the left side should have been marked K_y instead of K_x and the ordinates at the right should have been lableed K_x instead of K_y, L/D. The values of the L/D are the same as those given at the left of the chart except that in this case the decimal point should be moved four places to the right giving a whole number having the same figures as those given in the last two decimal places. This change in the ordinates, of course, necessitates a corresponding change in the characteristic curves, it being necessary to transpose the inscriptions K_x and K_y in each case.

Current Standardization Work

THE changes which occur in the personnel of the Standards Committee following each Annual Meeting of the Society cause a short interval to elapse before the various Divisions are functioning with their usual activity. The work for the ensuing year is now well under way and some of the Divisions are busily engaged. A resume of the recent activities of the different Divisions is given below.

Frames Division

A meeting of the Frames Division was held on March 10 in Cleveland at which a general letter was drawn up covering the points on which the Division members desired to obtain information to base future work. Copies of the general letter will be sent at an early date to manufacturers and users interested.

Isolated Electric Lighting Plant Division.

A meeting of the engineering representatives of the isolated electric lighting plant manufacturers was held at the Hotel LaSalle, Chicago, Feb. 2. The primary purpose was to discuss a possible revision of the present S. A. E. standard for the rating of storage batteries for isolated electric lighting plants. As the personnel for 1921 of the Division in question had not been appointed at the time of the meeting, the action taken was unofficial so far as the Standards Committee is concerned, but was intended as a definite guide to the Division, when appointed, as to what it was thought should be done toward making the standard a better one and more generally accepted.

The discussion indicated that the present so-called 72-hr. intermittent rating is used largely for commercial purposes and is misleading to the non-technical mind. A recommendation was passed that the present 72-hr. rating be withdrawn and a continuous 8-hr. discharge rating substituted. While this proposal met with considerable favor, further discussion developed other suggestions, such as a compromise between the present and the proposed ratings, the proposed 8-hr. rating being used with reference to power for mechanical purposes and the present 72-hr. intermittent rating for lighting purposes. The voltages used and the types and methods of rating implements such as flatirons, washing machines and vacuum cleaners were taken up. Since the usual method of rating such apparatus is in watts, it was thought generally that a battery rating could be expressed in watts, but as the element of the time of discharge of the battery must be taken into consideration it was finally decided that each lighting plant manufacturer should study the possibility of using a battery watt-hour rating based on a 20-hr. discharge and have definite data prepared in time for the next meeting, which was tentatively scheduled for April 11 at Chicago. This will enable the S. A. E. Isolated Lighting Plant Division to meet with the Farm Lighting Plant Group of the Gas Engine & Farm Power Association, the spring meeting of which is tentatively scheduled to be held at about the time mentioned. Thus it will be possible to secure more general consideration of the new rating to be suggested by the Division.

Passenger-Car Body Division

An organization meeting of the Passenger-Car Body Division was held on March 11 in New York City. It was decided to concentrate the work of the Division on a small number of subjects which are considered the most important to the passenger-car body builders, assigning the different subjects to Subdivisions in order to facilitate the work.

Non-Ferrous Metals Division

The Subdivision on Die-Casting Alloys held a meeting on March 11 in New York City at which the subject of die-casting alloys was considered in the light of the recommendations made by the Non-Ferrous Metals Division members at the Division meeting in November. Analyses were decided upon for Specifications No. 20, 28 and 29 which will be sent to all the die-casting manufacturers for criticism and, if they meet with approval, will be submitted to the Non-Ferrous Metals Division.

Screw-Thread Division

The Screw-Thread Division held a meeting on March 12 at the Old Colony Club in Detroit. This first meeting of the Division was given over almost entirely to a general consideration of several subjects assigned by the Council. Subdivisions were appointed to carry on the work in connection with the several subjects until the next meeting.

Stationary Engine Division

Although the Division for 1921 had not been officially organized at that time invitations were sent to about 18 stationary engine builders or their representatives to attend a meeting of the Stationary Engine Division at Chicago on Feb. 1. It has been felt for some time that much could be done toward deriving and establishing suitable engineering standards applicable to stationary internal-combustion engines, particularly those employed for agricultural purposes. While this type of powerplant is somewhat limited as regards mobility it has come into general use for a number of purposes, such as driving lighting plants and operating milking and grinding machines, saws and other equipment. Since the work which this type of engine is called upon to perform is of a very rugged nature and it must operate with a minimum of attention, care and cost, the same degree of refinement has not been attained in its design as in the case of the automobile and other types used for transportation purposes. There are many features, however, which if properly standardized will mean large savings to the builders and a lower cost and a decrease in the amount of time lost by the operator in replacements and operation. The possibilities of standardizing certain features were discussed at this meeting and a general plan of procedure prepared.

At the meeting the subjects of belt speeds and lubricators and grease cups were considered. In connection with the former, charts and tables which were submitted by those in attendance including a number of very representative engine builders showed a wide divergence of belt and engine speeds. This it was stated not only caused much confusion in connection with the designing of power-driven farm equipment but was generally unnecessary. The tentative proposal for standardizing belt speeds which was prepared as a result of the meeting is given in the accompanying table.

TENTATIVE PROPOSAL FOR STANDARD BELT SPEEDS

Nominal Engine Rating, hp.	Belt Speed, ft. per min.
To and including 1½	600-650
1¾-2½	650-750
3-4	800-1,000
5-7	1,500-1,700
8-12	1,700-2,000

In arriving at these belt speeds the requirements for relatively low and high-speed driving equipment were considered as well as the differences in engine speeds and pulley diameters. The two latter factors can, of course, be left to the judgment of the engine builder, since if a standard belt speed is maintained they do not necessarily affect the operation of the driven apparatus. The members of the Division felt that this tentative proposal should be carefully studied, particularly by agricultural implement manufacturers with reference to its adaptability to their products, bearing in mind that while this proposal is intended to apply as far as possible to existing equipment, it is primarily intended as a means

of bringing widely differing practices together when new equipment is designed and built.

As considerable trouble is experienced by engine builders by the differences in size of the body and sight glasses used on lubricators and grease cups, the Division is obtaining data from the manufacturers of these parts with the view to establishing a standard method of numbering the various sizes and standardizing the capacity and pipe connection dimensions for each size. As grease cups are used on some engines in places where others use lubricators, it is planned to include grease cups in this program.

The work most actively in progress has been assigned to 10 Subdivisions to facilitate the necessary investigation and preparation of a report to the Division at its next meeting, which has been tentatively scheduled to be held in Chicago on April 8.

Result of Standards Letter Ballot

At the Annual Meeting of the Society held on Jan. 11 the 32 recommendations of the 12 Divisions of the Standards Committee reporting were approved for final presentation to the voting members of the Society. These were adopted in their entirety by the letter ballot which closed on March 12. The reports on which this action was taken were printed on pages 169 to 199 inclusive in the February issue of THE JOURNAL.

The complete vote on the recommendations is tabulated below. The first column gives the number of affirmative votes cast; the second, the negative votes; and the third, the number of members who did not vote either way.

Aeronautic Division			
Turnbuckles	128	0	268
Special Report of the Aeronautic Division on the Regulation of Commercial Air Navigation	120	0	276
Ball and Roller Bearings Division			
Shaft and Housing Fits and Tolerances for Ball Bearings	226	7	163
Annular Ball Bearings, Separable (Open) Type	229	3	164
Annular Ball Bearings, Wide Type	232	1	163
Angular Contact Ball Bearings	230	3	163
Electric Transportation Division			
Electric Vehicle Storage Battery Jars	118	0	278
Electrical Equipment Division			
Storage Batteries	199	9	188
Fuses and Fuse Clips	211	1	184
Spark-Plug Tests	225	4	167
Magneto Dimensions	222	0	174
Starting-Motor Pinions	224	4	168
Brushes	198	3	195
Addition of Electrical Appliances	208	1	187
Engine Division			
Mufflers	196	18	182
Flywheel Housings	227	2	167
Fan Belts and Pulleys	223	1	172
Carbureter Intakes	229	1	166
Carbureter Air Heaters	227	3	166
Miscellaneous Division			
American Standard Taper Pipe Threads	247	1	148
Oil and Grease-Cup Threads	232	4	160
Motorcycle Division			
Spokes and Nipples	81	1	314
Motorcycle Wheels and Rims	85	1	310
Motorcycle Controls	75	2	319
Non-Ferrous Metals Division			
Non-Ferrous Metal Specifications	220	1	175
Radiator Division			
Cast Radiators	183	6	207
Passenger Car Radiators	197	2	197
Tire and Rim Division			
Wood Felloe Dimensions for Pneumatic Tire Rims	175	1	220
Tractor Division			
Tractor Belts and Pulleys	140	3	253
Tractor Engine Governors	146	0	250
Truck Division			
Rim Clamp Bolts	159	3	234
Wood Spokes for Passenger Car Wheels	158	4	234

Of the 2729 ballots mailed to the voting members, 396 valid ballots were cast or 14.5 per cent. This is an increase of 3 per cent over the August, 1920, and 1.5 per cent over the March, 1920, letter ballots.

Transmission Division

A meeting of the Transmission Division was held on March 14 in Detroit at which the regular Division subjects of clutch facings, gear-tooth pressures and transmission drives for speedometers were studied. The subject of clutch-release thrust ball-bearings was considered, members of the Ball and Roller Bearings Subdivision on Thrust Ball-Bearings attended the meeting to discuss this subject jointly with the clutch manufacturers. The basis of the deliberations was the consolidated list of sizes used in the automotive industry during the year 1920, which was drawn up at a meeting of the Thrust Ball-Bearings Subdivision held early in January. It was felt that the standardization should be restricted to only the boundary dimensions and the ball sizes. The consolidated list of sizes discussed at the meeting is given in the accompanying table.

CONSOLIDATED LIST OF CLUTCH-RELEASE TYPE THRUST BALL-BEARINGS USED IN THE AUTOMOTIVE INDUSTRY DURING 1920

No.	Bore, in.	Outside Diameter, in.	Width, in.	Size of Balls, in.
1	1	1.90	0.636	5/16
2	1⅜	2¼	0.6811	5/16
3	1⅜	2.695	11/16	5/16
4	1 7/16	2 9/16	11/16	5/16
5	1⅝	2¾	11/16	5/16
6	1¾	3 3 32	13/16	5/16
7	1 13/16	3	¾	5/16
8	2	3½	11/16	5/16
9	2	3 3 16	¾	5/16
10	2	2 15/16	¾	5/16
11	2¼	3 5/16	¾	5/16 or ⅜
12	2¼	3 7/16	¾	⅜
13	2⅝	3 31/32	13/16	5/16
14	3¼	4⅛	11/16	5/16
15	3½	4.53	⅞	5/16

Truck Division

The discussion at the Standards Committee meeting in January with regard to the proposed standardization of front hubs for motor trucks was printed together with a resolution by the Truck Division of the Standards Committee as to the course to be followed by the Division.

A meeting of axle, bearing and wheel manufacturers was called by C. C. Carlton, president of the Wood Wheel Manufacturers' Association at Detroit, March 3, to discuss ways and means for the continuation of the hub standardization and the possibility of including both ball and roller bearings in this program. A subcommittee of ball-bearing manufacturers, of which T. V. Buchwalter was appointed chairman, reported that it seemed advisable for the subcommittee to take more time in the preparation of its report on the ap-

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OBITUARIES

WILLIAM H. VAN DERVOORT, a past-president of the Society and president of the Root & Van Dervoort Engineering Co., died at his home in Moline, Ill., Feb. 25, aged 51 years. His death was the result of an illness contracted while he, as a member of a commission of five American manufacturers representing the National Industrial Conference Board, was touring Europe early in 1919 to assist in the reconstruction of destroyed factories. While his health was never really good since his return from Europe in May, 1919, it improved slightly about a year ago, but at the commencement of the past winter Mr. Van Dervoort became ill and for months had been at the point of death.

Mr. Van Dervoort was born Feb. 28, 1869, at Ypsilanti, Mich. He attended the Michigan Agricultural College at Lansing as a student in the mechanical engineering department and after being graduated in 1889 with the degree of bachelor of science entered Cornell University, from which he was matriculated in 1893 with the degree of mechanical engineer. He accepted a position as assistant professor of mechanical engineering at the University of Illinois and remained there for six years until together with O. J. Root, who had been a classmate at Lansing, he organized the Root & Van Dervoort Engineering Co. to build gasoline engines and manufacture locomotive specialties. Mr. Van Dervoort at that time was vice-president and manager of the company, which was located at Champaign, Ill., but removed to East Moline in 1901. When the Moline Automobile Co. was organized 1903 he became its president and general manager and as new organizations were formed to take care of the various branches of the business he became their head.

Energetically devoted to the advancement of the gasoline engine industry, Mr. Van Dervoort visited South America in the winter of 1912-1913 in the interest of the extension of that trade, a trip that was highly successful. He was president of the Society in 1915 and served as president of the National Metal Trades Association for the years 1916-1917, this being the only instance that this organization has reelected a president. From 1908 to 1911 Mr. Van Dervoort was a member of the committee on management of the American Motor Car Manufacturers' Association and also held many important positions in the National Automobile Chamber of Commerce.

Early in the war, when the British Government enlisted the manufacturing facilities of America, the Root & Van Dervoort plant was chosen for the execution of important shell contracts. Upon the completion of this work Mr. Van Dervoort caused the plants which had been specially equipped for shell production to be closed and the machinery and equipment kept intact and under guard in readiness for the time when they might be called upon to serve this country. After the entrance of the United States into the war these plants were placed in operation and manufactured 8-in. gas shells for the War Department and 4-in. shells for the Navy Department. Soon after the United States entered war, Mr. Van Dervoort was appointed a member of the Munitions Standards Board and was selected by the manufacturers to act as a member of the National War Labor Conference Board, he later being appointed a member of the United States War Labor Board by President Wilson. During the war he gave practically all his time to work for the Government.

In addition to his activities as an engineer, Mr. Van Dervoort was widely recognized as an authority on mechanical engineering and was the author of a textbook on Machine Shop Tools and Shop Practice. A number of articles in scientific and technical publications were written by him and because of his technical knowledge and intimate acquaintance with industrial questions he was frequently called upon to address scientific and business organizations.

He is survived by a widow and two daughters. He was elected to Member grade in the Society, in 1908.

All who came in contact with Mr. Van Dervoort admired him for his abilities and loved him for his personal qualities. He was one of the best friends the Society ever had. His conspicuous and valuable service to industry and the nation

WILLIAM H. VAN DERVOORT

constitutes a record that is very dear as well as gratifying to us. His relations with the Society as member and president are cherished as being among our best traditions. Mr. Van Dervoort as a man was an example of fairmindedness and sense of propriety to be followed by all. The conscientiousness and effectiveness that he demonstrated during his administration as president of the Society were very beneficial to and will be long remembered by the members.

WILLIAM BENTON CRISP died at his home in New York City, Jan. 28, aged 60 years. He was born at Fairfield, Anne Arundel Co., Maryland, on April 16, 1860, and entered Johns Hopkins University in 1879 where he took a special course in chemistry and physics. In 1882 he entered the Law School of Columbia University, being graduated therefrom in 1884. He then opened a law office at Baltimore and conducted a successful practice in that city until 1891 when he came to New York City. His specialty was banking, corporation, patent and commercial law.

Mr. Crisp was probably best known to the automotive industry from his connection with the famous Selden patent case in which he represented the interests of the Ford Motor Co. Another important case with which he was connected was the litigation instituted by Wilbur and Orville Wright against the Curtiss Aeroplane Co., which involved the basic patents on airplanes. In that case Mr. Crisp defended Glenn H. Curtiss and the Curtiss organization. His interest in the science of aviation resulted in his being one of the incorporators of the Manufacturers Aircraft Association, which was organized in 1917 and at the time of his death he was one of the trustees of this organization. He is survived by his widow and two sons, one of whom was his partner in the law firm of Crisp, Randall and Crisp. Mr. Crisp was elected to Associate Member Grade in the Society Feb. 1, 1917.

DANA MCGUFFEY LASLEY died in the Parker Hospital, Detroit, Feb. 20, following an operation for appendicitis. He was born at Columbus, Ohio, May 11, 1885, and re-

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Publications of Interest *to* S. A. E. Members

In this column are given brief items regarding technical books and publications on automotive subjects. As a general rule, no attempt is made to give an exhaustive review of the books, the purpose of this section of THE JOURNAL being rather to indicate from time to time what literature relating to the automotive industry has been published with a short statement of the contents.

USE OF THE MACMICHAEL VISCOSIMETER IN TESTING PETROLEUM PRODUCTS. By W. H. Herschel and E. W. Dean. Reports of Investigations Serial No. 2201. Published by the Bureau of Mines, Washington. 12 pages.

The common practice of the petroleum industry is to measure viscosity by instruments of the efflux or capillary tube type, notably the Saybolt universal viscosimeter. They have, however, certain limitations and for special types of work there are notable advantages incident to the use of the so-called torsion type of viscosimeter, the most satisfactory available type of which seems to be that of MacMichael. The report indicates conditions under which this viscosimeter can be used to advantage in the petroleum laboratory and outlines simple methods of operation and calibration.

PROPERTIES OF THE ARC-FUSED METAL. By Henry S. Rawdon, Edward C. Groesbeck and Louis Jordan. Bureau of Standards Technologic Paper No. 179. Published by the Superintendent of Documents, Government Printing Office, Washington. 63 pages.

The results of the investigation here given relate principally to the nature and characteristic properties of the arc weld, and in particular those of the "fused-in" metal. Since the metal of any weld produced by the electric-arc fusion method is essentially a casting, it is apparent that the efficiency of the weld is dependent upon the properties of this arc-fused metal. A considerable number of examinations was made of welds prepared by the electric-arc process and representative of different conditions of welding. In addition to mechanical tests the specimens were examined very carefully with a microscope. The results of the mechanical tests given are of value in that they are indicative of the average mechanical properties which should be expected in electric-arc welds of satisfactory grade and of the shape and size of those examined.

THE SAYBOLT FUROL VISCOSIMETER. By E. W. Dean. Reports of Investigations Serial No. 2215. Published by the Bureau of Mines, Washington. 4 pages.

The Saybolt furol viscosimeter, to be used at a temperature of 50 deg. cent. (122 deg. fahr.), has been adopted by the Bureau of Mines, and the Committee on Standardization of Petroleum Specifications, as official for the testing of "heavy" fuel oils. The features of this instrument are described and the history of its development given.

CARBONIZATION OF LUBRICATING OILS. Bureau of Standards Circular No. 99. Published by the Superintendent of Documents, Government Printing Office, Washington. 44 pages.

The nature and effects of the deposits formed in internal-combustion engines are discussed. It is shown that the term "carbon" is a misnomer, because the deposits consist largely of asphaltic matter. Brief accounts are given of the nature of petroleum oils and of the theories concerning the formation of deposits. The oxidation and cracking of petroleum are discussed in detail. Carbonization tests which depend upon oxidation and upon cracking are next taken up. Full descriptions of the apparatus and procedures for the Waters and Conradson carbon residue tests are given. Distillation methods are touched upon. It is pointed out that there is yet much to be learned upon the whole subject of the lubrication of internal-combustion engines.

THE SHIFT OF THE ANGLE OF NO-LIFT ON PROPELLER AIRFOILS. Air Service Information Circular, vol. II, No. 147. Published by Chief of Air Service, Washington. 3 pages.

Tests were run for the purpose of securing improved conceptions regarding the use of airfoils in propeller design. Evidence regarding a change in the angle of no-lift, depending upon the velocity, has been investigated as having significance in propeller design.

TEST OF REVISIONS IN COOLING SYSTEMS FOR AIR-COOLED CYLINDERS. Air Service Information Circular, vol. II, No. 124. Published by Chief of Air Service, Washington. 18 pages.

Four types of collectors or baffles were made up of welded sheet steel, the object of the design in each type being to direct the flow of the air to the rear of the cylinder, thus reducing the temperature at that location. These were tested and one type selected as most suitable.

BIBLIOGRAPHY OF PETROLEUM AND ALLIED SUBSTANCES IN 1918. By E. H. Burroughs. Bureau of Mines Bulletin No. 189. Published by Bureau of Mines, Washington. 180 pages.

This bulletin, the fourth in a series of petroleum bibliographies being published by the Bureau of Mines, indexes the articles and books published in 1918 on the utilization of petroleum products as well as their production. The internal-combustion engine classification covers 15 pages.

THE DESIGN OF WIND TUNNELS AND WIND-TUNNEL PROPELLERS. By F. H. Norton. National Advisory Committee for Aeronautics Report No. 98. Published by the National Advisory Committee for Aeronautics, Washington. 10 pages.

This is a continuation of Report No. 73 of the National Advisory Committee for Aeronautics and was undertaken for the purpose of supplying further data to the designer of wind tunnels. Particular emphasis was placed on the study of directional variation in the wind stream. It was found that placing radial vanes directly before the propeller actually increased the efficiency of the tunnel to a considerable extent. The placing of a honeycomb at the mouth of the experimental portion was of the greatest aid in improving the flow, but somewhat reduced the efficiency.

SOME ITEMS OF INVESTMENT, EXPENSE AND PROFIT IN COMMERCIAL SHALE-OIL PRODUCTION. By L. H. Sharp and A. T. Strunk. Reports of Investigations Serial No. 2214. Published by the Bureau of Mines, Washington. 3 pages.

Many opinions have been expressed regarding the possibilities of profitably engaging in the manufacture of shale oil. A general outline of the principal items of investment, expense and profit is given in this report for the information of those who have not considered the variety and scope of equipment necessary to commercial production of shale oil.

A HIGH-SPEED ENGINE PRESSURE INDICATOR OF THE BALANCED-DIAPHRAGM TYPE. By H. C. Dickinson and F. B. Newell. National Advisory Committee for Aeronautics Report No. 107. Published by National Advisory Committee for Aeronautics, Washington. 15 pages.

This report describes a pressure-measuring device especially adapted for use in mapping indicator diagrams of high-speed internal-combustion engines. The cards are obtained by a point-to-point method giving the average of a large number of engine cycles. The principle involved is the balancing of the engine cylinder pressure against a measured pressure on the opposite side of a metal diaphragm of negligible stiffness. In its application as an engine indicator the phase of the engine cycle to which a pressure measurement corresponds is selected by a timing device. The report discusses briefly the errors which must be avoided in the development of an indicator for light high-speed engines where vibration is serious and outlines the principles underlying the design of this instrument to be free of such errors. A

detailed description of the instrument and accessories follows, together with operating directions. Specimen indicator diagrams are appended. The indicator has been used successfully at speeds up to 2600 r.p.m., the highest speed engine available for trial. Its sensitivity is approximately that of a standard 6-in. dial gage of the Bourdon tube type.

CAUSES OF CRACKING OF IGNITION CABLE. By F. B. Silsbee. National Advisory Committee for Aeronautics Technical Note No. 32. Published by National Advisory Committee for Aeronautics, Washington. 16 pages.

Experiments are described which show that the cracking at sharp bends, observed in the insulation of high-tension ignition wires after service, is due to a chemical attack upon the rubber by the ozone produced by the electric discharge which takes place at the surface of the cable. Cracking does not occur if the insulating material is not under tension, or if the cable is surrounded by some medium other than air; but does occur even if the insulation is not subjected to electric stress, provided the atmosphere near the cable contains ozone. The extent of cracking can be materially reduced by using braided cable and by avoiding sharp bends.

DESIGN OF STANDARD LUGS. Air Service Information Circular, vol. II, No. 152. Published by the Chief of Air Service, Washington.

This report describes extensive experiments conducted to determine the proper proportions of the lug ends of airplane sheet-metal wing fittings to which the cable and turnbuckle ends attach. Standard lugs are presented which are based on the test results.

PERFORMANCE TEST OF JUNKER SL-6 AIRPLANE WITH 185-HP. B M W ENGINE. Air Service Information Circular, vol. II, No. 173. Published by the Chief of Air Service. Washington. 7 pages.

This report contains dimensional and performance test data of this well-known German metal monoplane with the observations of the test pilots regarding its flying qualities.

DEPRECIATION

ALTHOUGH virtually all of the great nations of Europe have enacted laws prohibiting the payment of dividends before charging off depreciation, until a few years ago the true nature of depreciation was not generally understood in the United States. Many of our courts formerly held that depreciation was not an element of cost and hence should not be deducted from gross earnings. For example, the Supreme Court rendered the following decision: "We are clearly of the opinion that it is not a proper charge. Only such expenditures as are actually made can with any propriety be claimed as a deduction from earnings." That this decision has been inferentially if not actually reversed is apparent from the rulings of the Interstate Commerce Commission in regard to the depreciation of railroad equipment.

As conditions vary so much it is not safe to establish standard rates of depreciation, but each case must be judged on its individual merits in the light of experience. For example, a stone or concrete storehouse may have a life of 50 years or more while a corrugated iron building subject to the shocks of heavy machinery and to the corrosive effects of gases might not be serviceable one quarter of that time. Machinery depreciates more rapidly than buildings, but varies within wide limits. As a rough guide for favorable conditions, a commission of the National Machine Tool Builders Association recommended an annual depreciation from the first cost of 10 per cent on machinery, 5 per cent on frame buildings and 3 per cent on brick buildings.—J. D. Skinner in *Army Ordnance*.

OBITUARIES

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ceived his technical education at the George Washington and Ohio State Universities, being graduated from the former in 1911 with the degree of Bachelor of Science in Mechanical Engineering, while the degree of Master of Science was conferred upon him the following year by the Ohio State University. For two years after being graduated from college he was chief engineer of the Differential Co. and was engaged in the development of a gearless differential. In 1914 he went with the Chalmers Motor Co. as sales engineer and was engaged in the sales promotion work and acted as a connecting link between the sales and engineering departments. He remained there for two years and then entered the service of the Domestic Engineering Co., Dayton, Ohio, as sales engineer. His duties there consisted of sales promotion work and the developing of a sales and service organization.

In 1917 he resigned to enter the service of the Government in the Ordnance Department, being commissioned as a lieutenant and subsequently was promoted to the rank of captain. He was in charge of the Ordnance Experimental Station at Indianapolis and helped to develop the 5-ton artillery tractor. In 1919 he was discharged from the Government service and accepted a position as sales manager of the motor division of the Wellman-Seaver-Morgan Co., Akron, Ohio. At the time of his death he was sales engineer of the Hercules Motor Co., Canton, Ohio. Mr. Lasley, who leaves a widow, was elected to Member grade in the Society, April 9, 1920.

CURRENT STANDARDIZATION WORK

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plication of ball bearings in the proposed standard hubs. It was thereupon decided that the matter be postponed until April 4, at which time the subcommittee would report definitely.

A meeting of the Truck Division was held in Detroit on March 15. The principal subject discussed was motor-truck body-installation dimensions, a tentative Subdivision report, previously sent to the members of the Division, being presented by F. A. Whitten. The report was thoroughly considered in review of criticisms which had been received from representative motor-truck and motor-truck-body builders.

The Subdivision appointed to formulate a standard for the rear shaft-ends of the front shaft of three-joint propeller-shafts reported progress. The members of this Subdivision are J. R. Coleman, chairman, H. B. Knap and J. W. B. Pearce. It is thought that three-joint propeller-shafts have been in use long enough to permit standardizing the particular portion of the shaft mentioned, which it is hoped will result in a great saving to both the manufacturer and to the user.

It was decided that no action should be taken relative to hub standardization until after the meeting of the subcommittee on April 4. A meeting of the Truck Division has accordingly been tentatively scheduled for April 18 to consider the subject of hub standardization further, and if possible to formulate a report to be submitted to the Standards Committee meeting on May 24 at West Baden, Ind.

Applicants *for* Membership

The applications for membership received between Feb. 28 and March 19, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ABELL, ROLLIN, mechanical engineer, Duesenberg Bros., *Elizabeth, N. J.*

BACKUS, HAROLD A., head of testing and inspection department, Gallaudet Aircraft Corporation, *East Greenwich, R. I.*

BARBECK, PETER, master mechanic, F. V. F. Machine Works, *New York City.*

BECH, C. O., engineer, Texas Co., *New York City.*

BECK, CHARLES EDGAR, sales engineer, Busch-Sulzer Bros. Diesel Engine Co., *St. Louis.*

BENEDICT, MAJOR CHARLES C., engineering division, Air Service, McCook Field, *Dayton, Ohio.*

BEST, HARRY A., sales representative, Sheldon Axle & Spring Co., *Wilkes-Barre, Pa.*

BLANCHARD, HARRY G., factory manager, Coast Tire & Rubber Co., *Oakland, Cal.*

BOONE, FIRST-LIEUT. MILTON O., motor transport, *Camp Sherman, Ohio.*

BOURNE, PHILLIPS P., chief engineer, Blake & Knowles Works, Worthington Pump & Machinery Corporation, *East Cambridge, Mass.*

BOYNE, WILLIAM K., airplane designer, *Stamford, Conn.*

CALDWELL, WILLIAM E., assistant manager of sales, Cleveland Twist Drill Co., *Cleveland.*

CARTER, CLAUDE, automobile shop foreman, Chris. C. Fausner, *Jamaica, N. Y.*

CARVER, W. L., general manager, Antigo Tractor Corporation, *Antigo, Wis.*

COLE, WALTER C., vice-president and general manager, William N. Albee Co., *Detroit.*

COLLINS, ALFRED S., electrician, Franklin Service & Repair Co., *Brooklyn, N. Y.*

DAVIS, JAMES H., farm engineer, General Motors Research Corporation, *Dayton, Ohio.*

DICHMAN, FIRST LIEUT. ERNEST W., engineering division, Air Service, McCook Field, *Dayton, Ohio.*

DOMONOSKE, ARTHUR B., assistant professor of mechanical engineering and director of shops, University of California, *Berkeley, Cal.*

DRAKE, HARCOURT C., engineer, Sperry Gyroscope Co., *Brooklyn, N. Y.*

DUESENBERG, WESLEY C., assistant superintendent, Kenworthy Motors Corporation, *Mishawaka, Ind.*

DUNCAN, CLEMENT, service manager on carburetion work, Zenith Carbureter Co., *Los Angeles, Cal.*

EDGARTON, LEWIS S., student, Massachusetts Institute of Technology, *Cambridge, Mass.*

EYMAN, ERNEST E., salesman, National Malleable Castings Co., *Cleveland.*

FAUST, WALTER L., student, Stevens Institute of Technology, *Hoboken, N. J.*

FRANZBLAU, JOSEPH, automotive instructor, Army vocational schools, *Fort Slocum, N. Y.*

GEE, HAROLD W., assistant engineer, White Hickory Wagon Mfg. Co., *East Point, Ga.*

GRIGNARD, EMILE E., district manager, Crew-Levick Co., *Philadelphia.*

GUSTAFSSON, BIRGER G., tool and die designer, Arvac Mfg. Co., *Anderson, Ind.*

HEDENE, EDWIN E., chief draftsman, Standard Gas Engine Co., *Oakland, Cal.*

HENDRY, M. JAMES, development engineer, International Harvester Co., *Chicago.*

HITKE, KURT, superintendent, Kenworthy Motors Corporation, *Mishawaka, Ind.*

HOFFMAN, MAJOR E. L., chief of equipment section, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

INSLEY, ROBERT, aeronautical mechanical engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

JACKSON, THOMAS, detailer, Holt Mfg. Co., *Peoria, Ill.*

JOHNSTONE, LLOYD G., JR., general manager, Gilbert Motors Co., *Boston.*

JUDSON, ROSS W., president, Continental Motors Corporation, *Grosse Pointe Park, Mich.*

KING, HAROLD L., mechanical draftsman, tank, tractor and trailer division, Ordnance Department, *Syracuse, N. Y.*

KINSTLER, LEON L., automotive inspector, motors and vehicles section, Army Supply Base, *Brooklyn, N. Y.*

LEVINE, BERNARD, foreman, Packard Motor Car Co., *Long Island City, N. Y.*

LINEK, JOSEPH, JR., foreman, J. Linek, *Maspeth, N. Y.*

LOUGH, HECTOR V., consulting engineer, Hartford Rubber Works Co., *Hartford, Conn.*

LOVE, HARDY C., factory representative, Willard Storage Battery Co., *Cleveland.*

MCCULLOUGH, R. C., director of distribution, Dura Mechanical Hardware Co., *Toledo.*

MCMAHON, JAMES J., designer, Mercury Motors Corporation, *Pittsburgh.*

MANNIEN, ARVO, student, Virginia Vocational High School, *Virginia, Minn.*

MATSON, HUGO WILFRED, Virginia Vocational High School, *Virginia, Minn.*

MIQUELON, P. E., branch manager, Zenith Carbureter Co., *Detroit.*

NEIGHBOR, L. B., experimental engineer, Marseilles Works, *East Moline, Ill.*

NELSON, RALPH N., president, Alloys Motor Parts Mfg. Co., *Tacoma, Wash.*

OLLEY, MAURICE, engineer, Rolls-Royce of America, Inc., *Springfield, Mass.*

OPITZ, F. M., president and factory manager, Perfex Radiator Co., *Racine, Wis.*

PARDEE, HOMER A., vice-president and general manager, Halcomb Steel Co., *Syracuse, N. Y.*

PETERSON, GUSTAF, general manager of sales, Electric Alloy Steel Co., *Youngstown, Ohio.*

POTTER, ALBERT T., chief engineer, Ainsworth Mfg. Co., *Detroit.*

PRICE, JOHN C., mechanical engineer, Jones & Lamson Machine Co., *Springfield, Vt.*

ROSS, ROBERT I., motor truck salesman, Giant Motor Truck Co. Ltd., *Vancouver, B. C.*

RUNCIMAN, H. D., secretary and general manager, Hoover Steel Ball Co., *Ann Arbor, Mich.*

SAKS, IRA, executive, Pennsylvania Piston Ring Co., *Cleveland.*

SATER, CHESTER W., supervisor of transportation, Great Atlantic & Pacific Tea Co., *Jersey City, N. J.*

SAUER, HERBERT F., manager Cleveland branch, Electric Storage Battery Co., *Philadelphia.*

SEWARD, WALTER E., technical school director, Y. M. C. A., *Canton, Ohio.*

SHARP, CLAYTON H., technical director, Electrical Testing Laboratories, *New York City.*

SLAGLE, ALFRED M., designing engineer, Two-Way Plow Tractor Syndicate, *Dayton, Ohio.*

SLOAN, FIRST-LIEUT. KELLOGG, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

STEINBECK, PAUL W., body engineer, H. H. Babcock Co., *Watertown, N. Y.*

THOMPSON, R. M., wholesale manager, Stutz Motor Car Co. of America, *Chicago.*

TIPTON, WILLIAM D., graduate student, Johns Hopkins University, *Baltimore.*

VALIANT, FRANK LIBBEY, sales engineer, Arvac Mfg. Co., *Anderson, Ind.*

WAGNER, HARRY S., draftsman, 19 Pinehurst Avenue, *New York City.*

WEDDLE, ALFRED H., draftsman, Schatz Mfg. Co., *Arlington, N. Y.*

WESSELLS, WALTER B., student, Johns Hopkins University, *Baltimore, Md.*

WILLIS, REX C., owner, Willis Bros., *Yakima, Wash.*

WOOD, J. E., district sales manager, Roller-Smith Co. of New York, *New York City.*

WORK, ROBERT VAN-HORN, student, University of Colorado, *Boulder, Col.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Feb. 10 and March 10, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

AHLENE, C. M. (A) sales and service engineer, Borg & Beck Co., *Moline, Ill.*, (mail) 1832 16th Avenue.

ALLEN, CARLOS H. (M) engineer, New Departure Mfg. Co., 3044 West Grand Boulevard, *Detroit.*

ALTON, DARREL D. (J) designer, Southern Motor Mfg. Association, Ltd., *Houston, Tex.*, (mail) 609½ Fannin Street.

ARMSTRONG, V. M. (A) assistant purchasing agent, Stutz Motor Car Co. of America, Inc., *Indianapolis.*

AUDE, JOHN R. (A) service manager, Chalmers Motor Sales Co., Brooklyn, N. Y., (mail) 211 Knapp Street, *Milwaukee.*

BACON, CHESTER A. (M) chief engineer, Auburn division, Bowen Products Corporation, *Auburn, N. Y.*, (mail) Logan Street.

BAGANZ, HERBERT MORRIS (E S) student, Purdue University, *Lafayette, Ind.*, (mail) 525 North Sixth Street.

BAILEY, CHARLES E. (A) sales and advertising manager, Paragon Motor Car Co., First National Bank Building, *Connellsville, Pa.*

BARTLETT, JOHN W. (A) engineer, Chase Tractors Corporation, Inc., 28 Atlantic Avenue, *Toronto, Ont., Can.*

BARTON, LOY E. (J) student, University of Arkansas, *Fayetteville, Ark.*, (mail) Box 238.

BEVERIDGE, FIRST-LIEUT. JOHN, JR. (S M) chief of engines branch, property division, Air Service, *Washington*, (mail) Copley Courts.

BORGEN, CARL K. (A) Walter M. Murphy Motors Co., 1429 Van Ness Street, *Fresno, Cal.*

BREVAIRE, A. A. (M) chief maintenance engineer, Hare's Motors, Inc., 16 West 61st Street, *New York City.*

BUCK, PORTER A. (J) assistant engineer, Power Truck & Tractor Co., *Detroit.*

BURDICK, RALPH M. (M) American Engine & Airplane Co., *Los Angeles, Cal.*

BURKE, EDMUND E. (E S) student, College of Engineering, University of Michigan, *Ann Arbor, Mich.*, (mail) 901 East Washington Street.

BUTCHER, LOWELL R. (J) experimental engineer, Porter Tractor Co., Newton, Iowa, (mail) 115 North Seventh Street, *East Newton.*

CLARK, REGINALD (A) assistant superintendent, J. H. Williams & Co., *Buffalo, N. Y.*, (mail) 221 North Park Avenue.

CORNELIUS, P. W. (J) tool design, Midwest Engine Co., *Indianapolis*, (mail) 47 Layman Avenue.

CRAMER, V. C. (A) branch manager, F. S. Carr Co., 42 Seldon Avenue, *Detroit.*

DAVIDSON, E. Y., Jr. (A) illuminating engineer, Macbeth-Evans Glass Co., *Pittsburgh.*

DE VIGNIER, ROBERT MOTT (M) chief engineer, American Vulcanized Fibre Co., Equitable Building, *Wilmington, Del.*

DICKSEE, CEDRIC BERNARD (M) mechanical engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., (mail) 222 Elm Street, *Edgewood Park, Swissvale, Pa.*

DOWNS, CHARLES W. (E S) student, Purdue University, *Lafayette, Ind.*, (mail) 3315 South Street.

DURLER, RUSSELL WALLACE (E S) student, Purdue University, Lafayette, Ind., (mail) 136 Sheetz Street, *West Fafayette, Ind.*

DRUMPELMANN, CARLTON T. (E S) student, Purdue University, *Lafayette, Ind.*, (mail) Sigma Chi House.

EDMUNDS, MARION K. (E S) student, Purdue University, Lafayette, Ind., (mail) 255 South Grant Street, *West Lafayette, Ind.*

FAHNESTOCK, MURRAY (A) technical editor, Trade Press Publishing Co., *Milwaukee*, (mail) 9 Marshall Avenue.

FLETCHER, V. H. (M) chief engineer, Curtis Motor Car Co., 318 Center Street, *Little Rock, Ark.*

FLOSS, CARL WILLIAM (J) draftsman, E. A. Nelson Automobile Co., *Detroit*, (mail) 2440 Parker Avenue.

FOSTER, H. F. (J) Ingersoll-Rand Co., *Athens, Pa.* (mail) Ingersoll-Rand Club.

FREYMAN, ARTHUR LEONARD (E S) student, Purdue University, Lafayette, Ind., (mail) 424 Dodge Street, *West Lafayette, Ind.*

FUNK, JAMES B. (M) branch manager, Champion Spark Plug Co., *Toledo.*

GESCHLIN, JOSEPH (J) production engineer, Duplex Engine Governor Co., Inc., *Brooklyn, N. Y.*, (mail) 294 Van Buren Street.

GIFFORD, ALBERT J. (M) partner, Leland-Gifford Co., *Worcester, Mass.*

GOTTLIEB, MARSHALL D. (J) mechanical engineer, Single Sleeve Motors, Inc., *Chicago*, (mail) 3027 Logan Boulevard.

GRAHAM, JAMES WILSON (M) designer, Hendee Mfg. Co., *Springfield, Mass.*, (mail) Suite 502, 774 State Street.

GREGG, JOHN WILLIAM (E S) student, Purdue University, Lafayette, Ind., (mail) 503 State Street, *West Lafayette, Ind.*

GRINER, RALPH C. (J) chief engineer, United States Tractor & Machinery Co., *Menasha, Wis.*

GRISWOLD, WALTER R. (J) engineer, Packard Motor Car Co., *Detroit*, (mail) 1732 East Grand Boulevard.

GRUENBERG, OTTO (E S) student, Tri-State College, *Angola, Ind.*, (mail) 509 West Maunee Street.

GRUNDY, GEORGE H. (A) general sales manager, Poldi Steel Corporation of America, 115 Broadway, *New York City.*

GUM, WILLIAM BURFORD (E S) student, Purdue University, (mail) Alpha Tau Omega House, 316 Russell Street, *West Lafayette, Ind*

HARTER, PAUL W. (E S) student, Purdue University, *Lafayette, Ind.*, (mail) 1200 Hartford Street.

HAWISHER, HAROLD H. (E S) student, Purdue University, Lafayette, Ind., (mail) 690 Waldron Street, *West Lafayette, Ind.*

HEDICAN, JOHN EDWARD (E S) student, University of Minnesota, Minneapolis, (mail) Box 540, *Virginia, Minn.*

HEIL, JULIUS P. (A) vice-president, Heil Co., *Milwaukee.*

HOLMES, BRADFORD B. (M) chief engineer, Miller Reese Hutchison, Inc., 51st floor, Woolworth Building, *New York City.*

HOLMGRAIN, E. O. (M) chief draftsman, O. E. Szekely Co., *Moline, Ill.*

IRONSIDE, FREDERICK MARTIN (A) mechanical engineer, E. W. Bliss Co., *Brooklyn, N. Y.*, (mail) 873 Park Place.

JENSEN, MILTON O. (J) engineer, Imperial Brass Mfg. Co., *Chicago*, (mail) 4647 Kenmore Avenue.

KING, LESLIE E. (J) solid and pneumatic tire designer, Kuhlke Machine Co., *Akron, Ohio.*

LEHMAN, HAROLD EDWARD (E S) student, Purdue University, Lafayette, Ind., (mail) Alpha Tau Omega House, 316 Russell Street, *West Lafayette, Ind.*

LEFEVRE, C. D. (M) sections secretary, Society of Automotive Engineers, Inc., 29 West 39th Street, *New York City.*

LINKERT, HOWARD WILLIAM (E S) student, Purdue University, Lafayette, Ind., (mail) 427 State Street, *West Lafayette, Ind.*

LUX, G. J. (M) chief engineer, Detroit Gear & Machine Co., *Detroit*, (mail) 3087 Garland Avenue.

MCCAMPBELL, PAUL R. (M) chief of development, G. & J. Tire Co., *Indianapolis.*

MCCARTY, HARRY HARPER (E S) student, Purdue University, *Lafayette, Ind.*

MCDONALD, HARRY T. (M) designer, Holt Mfg. Co., *Peoria, Ill.*, (mail) 417 California Avenue.

MCNAIR, JAMES TAYLOR (A) assistant service manager, Detroit Cadillac Motor Car Co., *New York City*, (mail) 8 West 62nd Street.

MALM, EDWIN LEMUEL (E S) student, University of Michigan, *Ann Arbor, Mich.*, (mail) Forest Hill.

MANVILLE, TRACY F. (A) general manager of sales, Columbia Steel & Shafting Co., *Pittsburgh*, (mail) 5822 Marlborough Street, East End.

MAURER, C. N. (A) mechanical engineer, Wisconsin Highway Commission, *Madison, Wis.*, (mail) 1212 West Johnson Street.

MARTY, BENJAMIN F. (A) equipment engineer, Ford Motor Car Co., *Highland Park, Mich.*, (mail) 219 Pilgrim Avenue.

MINER, ROBERT I. (A) sales engineer, Bossert Corporation, Utica, N. Y., (mail) 1513 Ford Building, *Detroit.*

MOGGE, ARTHUR R. (A) manager of advertising and sales production, Gibson Co., *Indianapolis*, (mail) Box 68, Y. M. C. A. Building.

MORITZ, JULIUS HOLLAND (J) designer, Garford Motor Truck Co., *Lima, Ohio*, (mail) 139 South West Street.

MOUGET, MARCEL G. (J) engineer, Western Electric Co., *Chicago*, (mail) 4506 Magnolia Avenue.

MUELLER, FRANK G. (M) chief engineer, Maccar Truck Co., Scranton, Pa., (mail) *Chinchilla, Pa.*

NEAL, JOHN FREDERICK (E S) student, Purdue University, Lafayette, Ind., (mail) 202 Littleton Street, *West Lafayette, Ind.*

NEUSTADT, FRANK (A) chief draftsman, Davis Sewing Machine Co., *Dayton, Ohio*, (mail) 739 Carlisle Avenue.

NORRIS, P. E. (M) production engineer, Westinghouse Union Battery Co., *Swissvale, Pa*

NYDEN, CLARENCE A. (J) experimental designer, Mitchell Motors Inc., Racine, Wis., (mail) 5043 North Robey Street, *Chicago.*

PETERS, JOHN F. P. (M) superintendent, Northway Motors Corporation, Natick, Mass., (mail) 27 Mount Hope Street, *Roslindale, Mass.*

PFEFFER, JOHN E. (M) mechanical and automotive engineer, Continental Engineering Co., *Chicago,* (mail) Suite 1032, 29 South LaSalle Street.

RHODES, CYRIL (E S) student, Purdue University, *Lafayette, Ind.,* (mail) 525 North Sixth Street.

ROBBINS, ROY MONROE (J) mechanical and automotive draftsman, Comet Automobile Co., *Decatur, Ill.,* (mail) 1159 North Union Street.

ROCKWELL, STANLEY PICKETT (M) metallurgist and chemist, Whitney Mfg. Co., *Hartford, Conn.*

ROGERS, DUDLEY T. (A) sales engineer, American Bosch Magneto Corporation, Springfield, Mass., (mail) 3737 South Michigan Avenue, *Chicago.*

ROLLER, WILLIAM F. C. (J) draftsman, William E. Quimby, Inc., *Newark, N. J.,* (mail) 764 Hunterdon Street.

ROOT, DONALD C. (A) sales engineer, Bridgeport Brass Co., *Bridgeport, Conn.*

ROSS, FRANK (M) superintendent, pressed steel division, Dodge Brothers, Detroit (mail) 162 Monterey Avenue, *Highland Park, Mich.*

ROUALET, ANDREW J. E. (A) experimental laboratory, F. B. Stearns Co., *Cleveland,* (mail) 12412 Euclid Avenue.

SAN DIEGO CONSOLIDATED GAS & ELECTRIC CO. (Aff) *San Diego, Cal.*
Representative:
Klauder, L. M., general superintendent.

SCHARMACH, FRANK WILLIAM (J) designer and layout man, Transport Truck Co., *Mount Pleasant, Mich.,* (mail) 326 North Main Street.

SCHROYER, EDGAR C. (E S) student, Purdue University, Lafayette, Ind., (mail) 453 Littleton Street, *West Lafayette, Ind.*

SCOBIE, VERNON (A) lecturer and instructor, West Side Y. M. C. A. Automobile School, *New York City,* (mail) 13 West 64th Street.

SHEAHAN, FRANK I. (J) Hart Roller Bearing Co., *Orange, N. J.,* (mail) 1 Baldwin Terrace.

SHERWOOD, RICHARD LYON (E S) student, Purdue University, Lafayette, Ind., (mail) 150 Littleton Street, *West Lafayette, Ind.*

SHORT, FRANK (A) expert, Ordnance Department, Frankford Arsenal, *Philadelphia* (mail) 3411 Walnut Street.

SILVERMAN, JESSE (J) manager of technical division, Syracuse Motor Car Co., Inc., 312 West Genesee Street, *Syracuse, N. Y.*

SMITH, CHARLES MACCABE (E S) student, Purdue University, *Lafayette, Ind.*

STOCKER, WILLIAM M. (M) mechanical engineer, Poole Engineering & Machine Co., *Baltimore,* (mail) 2103 Cliftwood Avenue.

STOLTING, FRED J. (J) draftsman, Holt Mfg. Co., Stockton, Cal., (mail) 225 5th Avenue, *Salt Lake City, Utah.*

STRADER, M. E. (J) draftsman, Fairbanks, Morse & Co., *Beloit, Wis.*

SYFAN, ROLLINS C. (A) assistant secretary, Stroud Motor Mfg. Association, *San Antonio, Tex.,* (mail) 807 West Mistletoe Avenue.

TABB, WARNER T. (M) chief engineer, Duplex Engineering Governor Co., Inc., *Brooklyn, N. Y.,* (mail) 194 Clinton Street.

TATU, CHARLES F. (J) 1771 Hertel Avenue, *Buffalo, N. Y.*

TAYLOR, ALBERT LEROY (M) assistant professor and mechanical engineer, University of Utah, *Salt Lake City, Utah,* (mail) 258 University Street.

TAYLOR, PAUL B. (J) engineer, Oakland Motor Car Co., *Pontiac, Mich.,* (mail) 56 Thorpe Street.

TAWRESEY, JOHN S. (J) assistant to chief engineer, Standard Steel & Bearings, Inc., *Philadelphia.*

THOMPSON, EDGAR LAURENCE (E S) student, Purdue University, Lafayette, Ind., (mail) 135 Sheetz Street, *West Lafayette, Ind.*

THOMPSON, J. K. (A) president and general manager, Auto Engineering Co., *Detroit,* (mail) 429 Bagg Street.

THWEATT, CARROLL P. (A) assistant inspection engineer, Eisemann Magneto Co., Brooklyn, N. Y., (mail) 202 East 32nd Street, *Baltimore, Md.*

WHITAKER, NORMAN T. (A) patent lawyer, Whitaker Building, *Washington.*

WILLSHAW, HARRY (A) assistant factory manager, Dunlop Tire & Rubber Goods Co. of America, *Buffalo, N. Y.,* (mail) 39 Granger Place.

ZIMMER R. R. (M) chief engineer, Du Pont Motors, Inc., Foot of Commerce Street, *Wilmington, Del.*

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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West Baden Meeting

AUTOMOTIVE engineering interest is directed this month to the State of Indiana and the Semi-Annual Meeting of the Society at West Baden, May 24 to 28. The reservations at this writing, five weeks in advance of the opening date, have passed the 400 mark and each mail increases the total. Fortunately, West Baden Springs Hotel has sufficient capacity to house a large convention comfortably and there are still many pleasant rooms available.

Outline of Technical Sessions

The programs of most of the technical sessions are completely arranged and the members will find them most interesting and instructive. The Research and the Fuel Sessions will undoubtedly rank first in point of general interest. As announced in the April issue of THE JOURNAL, Sir Dugald Clerk, the noted British scientist, had planned to visit America and attend the Summer Meeting. He has recently advised us by cable that illness in his family necessitates the cancellation of the trip at this time, but he has kindly forwarded the paper that he has written for the occasion and this will be discussed fully at the Research Session. There will be a paper on automotive engine and vehicle lubrication at this session by C. W. Stratford, whose previous contributions on the subject have created wide interest. Prof. W. E. Lay of the University of Michigan will present a paper on the automotive research facilities of the University, describing recent additions to the laboratory which will provide equipment for the study of the mechanical efficiency of the complete vehicle. The University of Michigan has recently established a Bureau of Research Investigation, and the faculty is anxious to cooperate with the industrial laboratories in attacking automotive research problems. There will undoubtedly be discussion of the research plan which the Society is contemplating and consideration given to the scope of this work.

The attainment of higher thermal efficiency in automotive engines and the employment of the less volatile oils as fuels will be treated by F. C. Ziesenheim of Carnegie Institute of Technology in his paper entitled Development of a High-Compression Oil Engine for Automotive Purposes. Dr. H. C. Dickinson and his colleagues, W. S. James and S. W. Sparrow, have prepared a most interesting paper analyzing the fundamentals affecting passenger-car economy. George P. Dorris has developed a new manifold intended to convert the less volatile ends of the fuel into vapor before they enter the cylinder, thus eliminating dilution of the lubricating oil. His paper will describe this, and models also will be shown.

Other technical sessions will be devoted to aircraft, farm power, highway transport, and engineering relation to sales. V. E. Clark's paper in the Aeronautic Session will tell of the economic reasons for the present unsatisfactory status of commercial aviation and suggest possible remedies. S. H. Philbin will emphasize the necessity of adequate Federal legislation to secure the support of the substantial business man for air transportation. G. J. Mead will read a paper on Aviation Powerplant Development, criticizing the present practice of powerplant installation in aircraft and pointing the way to probable future development.

The Meetings Committee has decided to postpone the Tractor Session which was planned for the Summer Meeting. It was thought that it would be better to arrange a special Tractor Meeting for some future date, probably in connection with one of the regional tractor demonstrations. The Committee on Plowing Speeds preferred to defer the conduct of further tests to a date later than that of the West Baden Meeting.

Owing to a decision to give preference to the papers of a strictly engineering nature, of which an embarrassing number were submitted to the Committee in view of the time available at the sessions scheduled, the Engineering Sales Stimulus Session has been eliminated.

Transportation Arrangements

The reduced-fare plan which has been arranged with the railroads differs from the one in effect at the Annual Meeting last January. A reduced-fare certificate will be mailed to all of the members about May 1. This must be presented when transportation to West Baden is purchased and entitles the member to a reduction of 25 per cent. Round-trip tickets only may be purchased under this plan, no stop-overs are allowed, and the same route must be used in both the trip to West Baden and return. These certificates can be used only in two of passenger

association territories whose boundaries include most of the automotive centers. A map which will be mailed with the certificates will show clearly the area in which the-fare-and-a-half round-trip plan applies. Special Pullman and train arrangements are described in this issue of THE JOURNAL under the Activities of the S.A.E. Sections.

SPORTS

The Committee in charge of sports is busy completing arrangements for one of the most comprehensive programs ever conducted at an S.A.E. summer meeting. No matter what your specialty may be, the Committee will see that you have an opportunity to demonstrate your prowess. There will be everything from a tug-of-war to croquet. Tournaments are planned for golf, tennis and trapshooting, and there will be two baseball series. The prize-fund appeal was answered most acceptably, assuring the selection of suitable and useful rewards for many engineer athletes. The ladies will find card parties, clock-golf, croquet and tennis tournaments arranged for them, not to mention the dancing contest that has proved so popular at past meetings.

Remember the date, May 24 to 28; the place, West Baden, Indiana; the numerous professional and recreational attractions; then send in your application at once.

DESIGN OF TRANSMISSION AND AXLE GEARS

THE design of automobile transmission and axle gears has always been one of the most vexing problems in design owing to the fact that the tooth pressures which prove satisfactory for and permit adequate durability with different materials, heat-treatments, tooth faces, pitches and speeds are most difficult to determine. With the advent of the truck and tractor the same difficulties have been experienced. The general practice is to calculate the strength of gears by the Lewis formula and then revise the dimensions as indicated by past experience as to wear and general satisfactory performance.

It has been suggested recently that, inasmuch as heat-treatments and materials for gears have been generally standardized by the industry and as the satisfactory tooth pressures for automobile, truck and tractor transmission and axle gears are well established, standards should be determined giving the maximum tooth pressures permissible for various types and dimensions of teeth for different materials. It is however recognized that such standardization would have to be predicated on a large amount of research work to establish reliable data relative to various factors that determine the smooth operation and life of gear mechanisms.

It is fully appreciated that the development of general formulas taking into account all the many variables would be most difficult. Transmission and axle manufacturers have done considerable experimental work along this line, but to study the importance of particular factors it has been necessary to restrict the experimental work to a great extent. To undertake any general investigation that would apply to all kinds of transmissions and differentials and the methods employed in their manufacture would involve an immense amount of work on the part of those conducting such an investigation and the trade.

The present practice for testing gears is to cut all of them under absolutely the same conditions on the same machine, using the same kind of cutting compound and the identical cutter, as all of these factors tend to affect the serviceability of the finished gear. It was originally thought that the Brinell or scleroscope hardness would be a very good index of the wear, but it was found that while it is a factor it does not bear a direct relation to wear. Gears cut from two different analyses of steel, hardened to exactly the same degree with all other conditions as nearly alike as possible, showed a marked difference in wearing quality. This indicates that if it is desired to derive a formula for figuring gear teeth which includes as a factor the analysis of the steel, the problem would be extremely complicated. It is generally agreed that definite factors for certain conditions which would indicate the wear which might be expected from gear trains would be well worth the necessary cost and effort of obtaining them.

INDUSTRIAL EMPLOYMENT ANALYSIS

THE United States Employment Service of the Department of Labor has made an analysis of the industrial employment situation, the results of which are of unusual interest at this time. The reports state that between January, 1920, and January, 1921, employment in general was decreased by 35 per cent, and that in the automobile industry the percentage of unemployment was as high as 69 per cent. During the two months of February and March of this year, however, a decided recovery has taken place. The number of persons employed in the automobile industry on March 31 was 52 per cent higher than on Jan. 31, although for the same period there was a further reduction of 2.5 per cent in the number of persons employed in all industries. This shows that while last year the automobile industry was the first to feel the falling off in business, it has on the other hand already started to recover substantially. It would seem from these figures that this industry might be considered as a barometer indicating several months in advance the probable trend of business in general.

The United States Employment Service has obtained this information from over 1400 firms, each normally employing over 500 men, representing 14 industrial groups subdivided according to geographical location. It is planned to make this survey continuous, and figures will be given out by the Department of Labor monthly, showing the employment situation throughout the country. These bulletins should be of extreme interest to every manufacturer as indicating not only business conditions but also the trend of wages and the purchasing power of the different sections of the country. These monthly analyses are issued under the title of Industrial Employment Survey Bulletins by the United States Employment Service, Department of Labor, Washington.

HIGHWAY TRANSPORT

I FIRMLY believe that the development of road construction and the use of the motor truck is the next great industrial development to take place in this country, and if intelligently considered and wisely applied, it will open up sources of immeasurable national wealth and contribute to the welfare and comfort of our people to a degree that has rarely, if ever, been equaled by any one method.—John S. Cravens.

UNITED STATES FOREIGN TRADE

UNPRECEDENTED totals were attained in American foreign trade for the fiscal year ended June 30, 1920. The merchandise that passed through our ports, in both directions, was valued at $13,349,661,401, exceeding by more than $3,000,000,000 the highest previous figure which was recorded in 1919. Imports of merchandise totaled $5,238,621,668, as compared with $3,095,720,068 in 1919 and $2,945,655,403 in 1918.

Nebraska Tractor Tests

By Oscar W. Sjogren[1]

Columbus Farm Power Meeting Paper *Illustrated with* Charts

BEFORE taking up the results of the Nebraska tractor tests, I believe it would be well to state briefly the provisions of the law, the kind of tests conducted and the equipment used, so that you may have somewhat of an idea of why and how the work is carried on.

Provisions of the Nebraska tractor law are as follows:

(1) A stock tractor of each model and type sold in the State shall be tested and passed upon by a board of three engineers under State University management

(2) Each company, dealer or individual who offers a tractor for sale in Nebraska shall have a permit issued by the State Railway Commission. The permit will be issued after a stock model of the tractor has been tested by the University and the performance of the tractor compared with the claims made for it by the manufacturer

(3) A service station with a full supply of replacement parts for any model of tractor sold in the State shall be maintained within the confines of the State and within reasonable shipping distance of customers

(4) Enforcement of the provision of the law is placed in the hands of the State Railway Commission

The official test includes a series of runs or tests as follows:

(1) Twelve-hour limbering-up run, beginning with one-third load and gradually increasing the load until the tractor pulls practically a full load for the last 3 of the 12 hr. The object of this test is to give an opportunity for the tractor to limber up under the supervision of a factory representative

(2) Brake-horsepower test at the rated load and speed for 2 hr. This gives an opportunity to observe the behavior of the tractor under its rated load and also gives a record of the fuel consumption

(3) Brake horsepower for 1 hr. at a load varying from the maximum to no load for 10-min. periods with the engine set as for the rated load test. This test continues for 1 hr. The object of this test is to show the fuel consumption under variable load and speed control of the governor

(4) Brake-horsepower test at maximum load for 1 hr. with the governor set to give full opening of the throttle-valve and the carbureter adjusted to give the maximum power at the rated speed

(5) Brake-horsepower test at one-half load for 1 hr. and the governor set as for rated load and carbureter adjusted for the most economical operation at this load

(6) Drawbar-horsepower test at the rated load for 10-hr. continuous run. This test is carried out on a half-mile cinder track, the load being the Nebraska dynamometer car which will be explained briefly later on

(7) Maximum drawbar-horsepower test. This test consists of a series of short runs with an increase of the load for each run until the engine is overloaded or the drive wheels slip excessively. We are contemplating making a change in this maximum test for the coming season, namely to continue it through a period of 1 hr. with the maximum load which the tractor will pull for that time. The purpose of the maximum drawbar test as conducted during last season was to determine what load the tractor could pull for short distances

(8) Miscellaneous test. This includes an investigation of work on inclines, turning radius, effectiveness of brakes, or any other feature which may seem to require special observation

The tractors are under observation throughout the complete test as outlined above. The length of the official tests varies from a minimum of 28 to a maximum of 54 hr.

Equipment Used

To carry out the work properly it was found that a special building would be necessary, inasmuch as no building was available, upon the campus, suitable for the purpose. A hollow-tile building was constructed, having a width of 41 ft. and a length of 82 ft. with 14-ft. ceiling. The question of ventilation and providing of outside air was gone into and to provide as free movement of air as possible very large door openings were used and an abundance of windows provided. The outside walls of the testing shed contain approximately 2340 sq. ft. of wall space. Of this area 294 sq. ft. consists of windows and 232 sq. ft. of door space, making a total of 526 sq. ft. of window and door openings, or approximately 22 per cent of the wall space. Besides this, two ventilators, in which exhaust fans are installed, are placed in the ceiling.

All brake tests were made on a Sprague electric dynamometer of 150-hp. capacity. This dynamometer is driven through an extension shaft mounted on ball bearings carrying a pulley 10 in. in diameter with a 12-in. face. No allowance is made for belt loss. Various types and sizes of belt are available to provide the builder with what he deems to be most suitable for his tractor, or he may provide his own belt if he so desires. Besides the dynamometer and the belts, various other equipment, such as scales, scale tanks, weighing-stands, speed-counters, tachometers, fuel-testing equipment, etc., is provided.

The drawbar tests were made on a half-mile cinder track, the surface of which is slightly rolling, no grade, however, being greater than 3½ per cent. To provide a load on the tractor which could be fairly well controlled at all times a special dynamometer car or loading machine was constructed which in the main consisted of a tractor chassis, carrying an electric generator mounted in place of the engine. This generator is driven from the drive-wheels as the car is pulled by the tractor. This machine furnishes a maximum drawbar pull of about 5000 lb.

[1] M.S.A.E.—Professor of agricultural engineering, University of Nebraska, Lincoln, Neb.

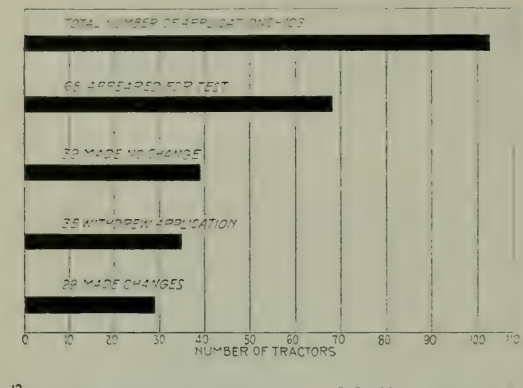


FIG. 1.—SUMMARY OF TRACTOR TESTS

When it is necessary to provide a greater drawbar pull than this, various loads are attached behind the car until the desired pull is obtained. The 10-hr. continuous run demanded by the law makes this part of the test the most difficult of all the runs.

A word may be said here of the operators in order that it may be understood that the various machines were operated by the same set of operators while records were taken. On the preliminary run a representative of the tractor firm operated the machine to be sure that it was working properly. On all other tests the University furnished its own operators, as this was thought to be the most satisfactory to all concerned.

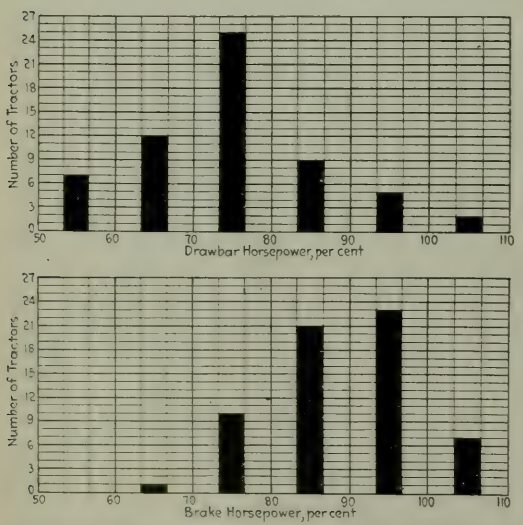


FIG. 2—RATED DRAWBAR AND BRAKE HORSEPOWER IN PERCENTAGES OF THE MAXIMUM DELIVERED IN THE TESTS

RESULTS OF THE TESTS

Applications covering 103 different tractors were received for the season. Of these 68 appeared for test, 35 withdrew their application without appearing for test. The reasons for withdrawal were various, such as models becoming obsolete, curtailing of production, restriction of territory, etc. Of the 68 which appeared for test 39 went through without making any changes, while 29 made changes as indicated in Fig. 1. Of the 11 which changed equipment, 2 also changed their rating. One of the three which withdrew later made reapplication, appeared and went through the test.

In the figures covering the belt horsepower and the drawbar horsepower the maximum delivered at the brake or drawbar has been used as a basis of 100 per cent and the rating is therefore given in percentages of maximum in Fig. 2. Three tractors were not rated and two have discontinued the belt rating. It is seen that only 11 machines come within the former S. A. E. Standard belt rating, while 51 machines carry a rating higher than was permitted by that standard.

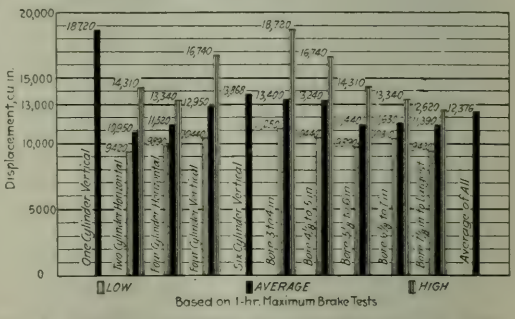


FIG. 3.—PISTON DISPLACEMENT PER HORSEPOWER-HOUR IN CUBIC INCHES FOR VARIOUS CLASSIFICATIONS OF TRACTORS

Studying the results of the drawbar tests, we find that this condition is changed, a more liberal rating being given on the drawbar work. It must be kept in mind, however, that this maximum drawbar horsepower from which these data are drawn is obtained during a very short interval of time. It serves, nevertheless, to indicate that the drawbar rating is more liberal than the belt rating. It is seen that 44 tractors fall within the former S. A. E. Standard drawbar rating, 7 being rated at approximately half of what they can do and 16 carrying a rating higher than the said standard indicated, 2 of these being rated at more than they can actually develop.

A chart compiled showing the cubic inch displacement per horsepower of various classifications of tractors and reproduced in Fig. 3 gives some interesting comparisons. These cubic inch displacement figures are all taken from the 1-hr. maximum belt test. Of the 65 tractors tested the lowest piston displacement is 9420 cu. in., which is for a two-cylinder horizontal machine. That this type, however, does not have a lower piston displacement than the other types is shown by the chart. The highest piston displacement is 18,720, which is for a one-cylinder vertical machine. This figure, being from only one machine, should not be taken as conclusive that all one-cylinder tractors have a high displacement. It is noted

that there is almost a 100 per cent variation in the piston displacement shown by the lowest and the highest, and that there is a great variation in each class as to the two classifications shown.

In the classification of tractors as to belt speed in feet per minute the results obtained are shown in Fig. 4. The standard belt speeds of 1500, 2600, 3000 and 3500 ft. per min., as adopted by the Society, and the additional speed of 3250 ft. per min., adopted by the National Implement and Vehicle Association, are shown at the base of this chart and are indicated by the heavy vertical lines. It will be interesting to compare the belt speeds a year or two after these standards have been in operation and note whether any effort is made to conform to the standards.

Fuel Consumption

The fuel consumption has been studied from the three different angles of volumetric displacement, engine speed

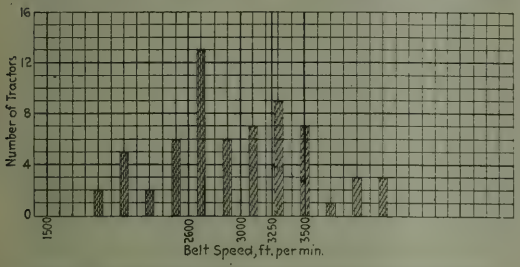


Fig. 4—Classification of Tractors According to Belt Speed

and the diameter of the cylinders. The curves reproduced in Figs. 5 and 6 do not happen to be smooth, but they indicate in a general way the relation of fuel consumption to those three factors. The lowest fuel consumption secured during the season on belt work was 0.63 lb. per hp-hr. with an air temperature of 58 deg. fahr., and the highest was 1.27 lb. per hp-hr. with an air temperature of 100 deg. fahr. On the drawbar work the lowest was 0.98 lb. per hp-hr. with an air temperature of 76 deg. fahr., and the highest was 3.02 lb. per hp-hr. with an air temperature of 89 deg. fahr. Table 1 gives the number of tractors in each class according to piston displacement.

Table 1—Classification of Tractors on Basis of Piston Displacement

Piston Displacement, cu. in. per min. per hp.	Number of Machines
9,000 to 10,000	3
10,000 to 11,000	7
11,000 to 12,000	10
12,000 to 13,000	19
13,000 to 14,000	12
14,000 to 15,000	7
15,000 to 16,000	4
Over 16,000	3

Table 2—Classification of Tractors According to Engine Speed

Speed, r.p.m.	Number of Machines
375 to 500	3
500 to 700	11
700 to 900	16
900 to 1,000	14
1,000 to 1,200	15
1,200 to 1,500	5
Above 1,500	1

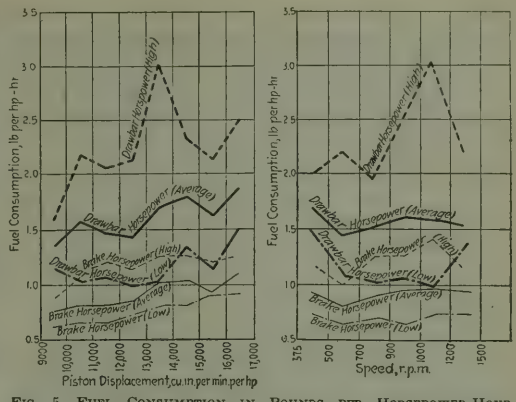


Fig. 5—Fuel Consumption in Pounds per Horsepower-Hour Based on the Piston Displacement in Cubic Inches per Minute per Horsepower at the Left and at the Right on Engine Speed

Based on engine speed, it will be seen that the fuel consumption tends to increase with the engine speed, although the difference is not great. The average shows a minimum of 0.8 lb. per hp. at about 600 r.p.m., it being greater at both higher and lower speeds. The number of tractors in each class is given in Table 2.

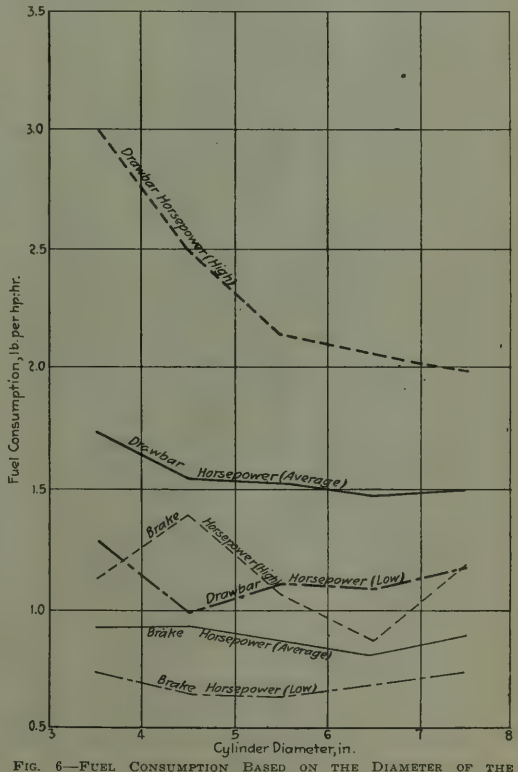


Fig. 6—Fuel Consumption Based on the Diameter of the Cylinders

Based on the diameter of the cylinders, the fuel consumption shows a tendency to decrease as the diameter of the piston increases until the 7-in. diameter is reached. As the diameter increases above that figure there seems to be a tendency for the fuel consumption curve to start upward. The number of tractors for this classification is divided as shown in Table 3.

TABLE 3—TRACTORS CLASSIFIED ACCORDING TO CYLINDER DIAMETERS

Cylinder Diameter, in.	Number of Machines
3 to 4	13
4⅛ to 5	28
5⅛ to 6	9
6⅛ to 7	8
Above 7	7

The water consumption per hour for the different tractors showed wide variation, running from no water used during the 2-hr. rated test at an air temperature of 84 deg. fahr. to 50 gal. for the same test when the air temperature rose to 88.5 deg. fahr. On the drawbar test the amount of water required varied from nothing at an air temperature of 77 deg. fahr. to 17.8 gal. per hr. with an air temperature of 87 deg. fahr.

Weak Spots

The weaknesses of the tractor are not discussed here with the idea of criticizing the builder, for we all know that he has enough troubles of his own, but rather with the thought of singling out some of the weaknesses that have been shown up in our work in Nebraska, in the hope that this will help to improve the product.

Some of the changes that were made while the tests were in progress were a direct result of placing the tractors in the hands of operators who had not worked with them at the factory and as a consequence were not familiar with every little peculiarity of the particular machine. Some of the weaker points which may have escaped the notice of the designer or which have been ignored have thus been brought out. No changes whatever were made as a result of incompetent operators; in every case the machines had a fair trial at the hands of the operators under the observation of the tractor representative. It has been noted throughout our tractor testing work that doubtless in many cases as the tractors have been tested at the factory defects have been overlooked by the tractor engineer in his desire to obtain results, and as a consequence when the tractor gets into the hands of the actual user trouble develops altogether too soon. I believe that much good would result if the tests at the factory could be run by men who have had nothing to do with the design of the machine and would therefore not be apt to pet it through the test.

Probably more trouble was found with fan-belts than with any other one thing and yet this appears to be a difficulty that could easily be remedied by increasing the size or altering the shape of belt or making changes in the type of fan drive. In other cases where difficulty was had to secure proper cooling a larger radiator or a larger fan was installed which improved materially the behavior of the tractor under load. In one instance it was found that the fan was of smaller diameter than called for by the specifications. It developed that a supply of these fans had been furnished to the builder of this tractor. For some reason they were not turned back but were used and as a result trouble developed when the tractor was put under a heavy load. Other cooling difficulties indicated that the water space, especially in the cylinder-heads, might be too small. This was indicated by the heads becoming very hot, giving considerable spark-plug trouble, and yet the cooling water did not reach a temperature of 200 deg. fahr.

That the problem of the amount and degree of heated air to be taken into the engine is not yet solved is indicated by the many cases where difficulty was had in maintaining the power of the engine as it became warmed-up. During the warming-up period the engine would perform well, holding its required load, but as the temperature of the cooling fluid became constant and the engine was working hard, the power output began to drop. Trials were then made by installing by-passes and shrouds which permitted the taking in of cold air in various amounts. It was found that if as the engine warmed up the amount of heated air admitted could be cut down and the amount of cold air increased, the power output could be maintained. This led some of the firms to install automatic air-heating regulating devices on their tractors with good success.

In some cases when it was impossible to obtain the rated horsepower from the engine, changes were made in the make and type of carbureter with very good results. This shows that close attention must be given to the choice of carbureter.

Where water is mixed with the fuel some method is necessary to give a close control of the amount supplied for this purpose. This was brought out very strikingly in some cases. In one instance in particular I recall that the engine would not develop within 2 hp. of its rating. By substituting a needle-valve for a globe-valve in the water line and adding a sight feed, the amount of water added could be regulated very closely, enabling the engine to develop power slightly above its rating.

Much remains to be learned about the design and use of air-cleaners. With the dry air-cleaners the most frequent difficulty seemed to be an effort to use a size entirely too small for the tractor, resulting in power below the rating. By disconnecting the cleaner in such instances the engine could develop its rating. The question of size is important also with the moist air-cleaners, as is the matter of replenishing the water supply while the engine is in operation. This latter is especially important when working the tractor on the belt. The farmer dislikes very much to have to stop the machine at frequent intervals to replenish the water in the cleaner and after some experience of this kind will likely disconnect it, thus losing the protection that it is supposed to provide.

It is probably superfluous to mention the inadvisability of the use of kerosene in a gasoline engine and yet it is permitted in some tractors with anything but satisfactory results. I believe that the builder of the gasoline tractor would save himself a lot of grief if he would discourage the use of kerosene in such a tractor.

The purpose of a governor on an engine is to prevent any appreciable variation in the engine speed. In many cases "governor" was a misnomer, while in others splendid results were obtained. The closest regulation given by any governor had a variation of 0.4 per cent above and 0.9 per cent below the rated speed. In this case the governor was set to give the rated speed of the engine while idling. The greatest variation was 55 per cent above the rated speed. Of the 65 tractors tested, 30 had governors which gave a speed regulation within 10 per cent of the rated speed, and 35 went above this figure. Of the latter, 13 varied more than 20 per cent and two more than 50 per cent above rated speed. In no case did the variation below rated speed exceed 7 per cent.

A study of the log sheets giving readings every 10 min. seems to indicate a close relation between the speed control and the fuel consumption. Where there is a fluctuation in the engine speed on the 2-hr. rated load test there is a corresponding fluctuation in the fuel consumption at each 10-min. interval and likewise where the speed is practically constant throughout this test the fuel consumption readings at the 10-min. intervals are more nearly constant. It seems, therefore, that in the interest of fuel economy a close regulating governor is desirable.

Belt pulleys of the types which can be attached or taken off readily gave considerable trouble. This is no doubt due to their having a short shaft and usually only one bearing. The pressure upon such an arrangement is large and subjects it to severe usage.

There was lack of proper clearance in some cases between the face of the belt pulley and the drive-wheels. Under wet-soil conditions this may give considerable difficulty by the filling on the drive-wheel rubbing on the belt pulley, thus causing a stalling of the engine. A desirable arrangement of the belt pulley and starting provision which is lacking on some tractors is the ability to crank the engine and start it while in the belt. This is very desirable from the standpoint of a "one-man machine."

The weight distribution or method of attaching the load or both are often such as to make the weight on the front wheels too little and as a result these wheels do not bear down upon the soil heavily enough to cause the tractor to turn readily, especially when pulling a heavy load. The guiding mechanism is in constant use while the tractor is operated on drawbar work. In view of this fact, it should be designed so as to be operated more easily on a number of machines.

More attention should be given to providing means for the operator's comfort and convenience in the matters of seat design and arrangement and accessibility to the various parts of the tractor for inspection, adjustment and repair. Often the seat is placed directly in the path of the fan blast, without any effort being made to deflect this blast of hot air and, consequently, the operator must endure this heat in addition to the hot weather during the working seasons. In other instances the operator is compelled to be seated astraddle of a transmission case which virtually becomes a boiling volcano. The matter of replenishing the supply of water in the cooling system and in the air-cleaner, as well as lubricating the tractor while it is in operation, seems to have been overlooked in a number of instances.

That the condition of the valves is looked upon by the factory as a minor matter is indicated by the fact that in 16 different tractors the valves were ground after the test was started, the power output being thereby materially increased. A number of these cases gave evidence of the work of fitting and grinding the valves having been improperly done at the factory. It should be remembered that the farmer and often the service man do not have at their disposal the equipment for this work that is available at the factory, and this should be given proper attention there. The farmer expects the newly purchased tractor to serve without the necessity of immediate attention to such matters and rightly so.

That the matter of proper spark-plugs has not been satisfactorily solved is shown by the records which disclose that 42 spark-plugs had to be replaced during the testing season. This in itself is not indicative of any serious difficulty in this respect, but when it is noted that the trouble was due to the points burning or breaking off and the blowing out of plugs, it indicates that some builders have not found a plug that works satisfactorily in their machines.

The changes made necessary in the large percentage of the tractors submitted for test indicate that the power ratings are made on too narrow a margin. Other tractors went through the tests with a very liberal margin above their rating. This wide difference should be eliminated and ratings made on a uniform basis. The sooner this is done the better it will be for the industry, as it will eliminate a large amount of suspicion on the part of the purchaser. If he can feel certain that a 30-60 tractor of one make is equal in power to a similarly rated tractor of any other make, he will have more confidence than he has now. The results of the test allow a comparison to be made of tractors using the same make and model of engine. For instance, three different tractors use the same 3⅛ x 4½-in. engine and are rated differently as is brought out in Table 4.

TABLE 4—DIFFERENCES IN THE RATING OF THREE TRACTORS USING THE SAME ENGINE

Tractor	Rating, hp.	Speed, r.p.m.	Maximum Belt Power, hp.	Drawbar Pull, lb.	Speed, m.p.h.	Power at Drawbar, hp.
A	6 to 12	1.000	12.37	1.142	2.06	6.27
B	5 to 10	1.000	11.34	1.139	1.79	5.66
C	6 to 10	1.200	13.31	1.310	2.84	9.92

Here is a variation in rating of *A* and *B* of more than 8 per cent and yet they have the same engine operating at the same speed. Tractor *C* is rated lower on the belt than *A* and yet the engine is operated at a greater speed. It is plainly evident that here are differences in rating for which there are no consistent reasons. The same condition holds true though not so markedly with larger tractors using an engine of the same make and size.

To sum up what has been said, the difficulties can be classified into five divisions. These are (*a*) engine troubles, which are dependent upon the design of the engine and the correlation of different parts; (*b*) accessory troubles, which depend upon the choice of the proper accessories and their adaptation to the engine; (*c*) proper correlation of the parts and the design of the chassis to fit the engine and permit the most efficient use of it; (*d*) testing of finished tractors by others than designing engineers to bring out minor difficulties; and (*e*) rating the tractors to give a liberal allowance for overload.

The Consequential Advantages of Weight Reduction

By L. H. Pomeroy[1]

Buffalo Section Paper

IT is generally admitted by engineers that any steps toward the reduction of chassis and body weights are desirable in the interests of economy but it is not unusual to find that weight reduction is looked upon as incompatible with reliability and road holding properties. The weight of an automobile chassis is determined on the one hand by the engine power and the required strength of the transmission to transmit the torque developed and on the other by the strength of the axles, springs and frame in their relation to the shocks imposed by road inequalities and driving strains. In brief, if automobiles had to be designed to run on railroad tracks up mountains the engine and transmission would be the chief determinant of the total weight as the shocks imposed on the axles and the frame would be very small. Conversely if automobiles had to be designed to run from the top of a mountain to the bottom over very rough roads the weight would be principally determined by the requirements of the frame, springs and axles.

Apropos of this the rear-axle is a member which supports the weight of the car and also transmits the engine torque to the wheels, while the front axle is virtually a load-carrying member solely, its stresses being independent of the engine torque for any given speed and car weight. It is a matter of simple calculation to determine the remarkably small average horsepower developed in the propulsion of a full-sized passenger car. At 30 m.p.h. this amounts to about 8 hp. and in the majority of cases is not more than 25 per cent of the horsepower available. Taking a typical case of an engine say of 240-cu. in. cylinder capacity, a gear ratio of 4.5 to 1 and 32-in. wheels, the engine speed corresponding to 30 m.p.h. is approximately 1350 r.p.m. while about 36 b.hp. is available at that speed. Approximately 4 hp. is absorbed in internal friction so that the 8 hp. required to propel the car is attended with a loss of 4 hp. and the mechanical efficiency of the engine under these conditions is only about 66 per cent. This simple calculation indicates the necessity not only of obtaining high mechanical efficiency in automobile engines, but of reducing the absolute friction loss as it is such a large proportion of the average power exerted. It is obvious that the larger the engine the greater the absolute loss and one of the consequential advantages of reducing the size of the engine, in addition to the reduction in weight, is that its absolute friction loss is proportionally reduced, apart altogether from mechanical efficiency as such.

Aluminum for Various Parts

The use of aluminum for pistons is a well-known method of reducing inertia stresses and bearing pressures and in conjunction with the use of forged aluminum connecting-rods reveals the possibilities of wholesale weight reduction. The factor which probably determines the maximum horsepower which can be continuously developed is the loading on the big end of the connecting-rod. This is very largely a function of the mass of the piston and connecting-rod at high speeds so that if this total mass can be halved as is easily possible by the use of aluminum, the safe engine speed can be increased over 40 per cent, or alternatively the same engine speed can be maintained with a 40 per cent reduction in the amount of bearing surface. I am fully aware of the difficulties in utilizing this idea to its fullest extent, but it is seriously suggested that the possibilities of weight saving by shortening bearing lengths is full of the greatest potentialities.

The example of the piston and connecting-rod, in which reliability is distinctly a function of their lightness and not of their weight, applies in general to all parts of an automobile in which the stresses are determined by road shocks and speed. It is of the utmost importance, therefore, in the interest of reliability to reduce the weight of all parts which are so stressed. This is particularly emphasized in axle design where the effect of road shocks is strictly proportional to the axle weight. In addition axle weight reduction brings with it enhanced road holding properties as the relation of sprung to unsprung weight is reduced. The argument in support of this is precisely analogous to that demonstrating the necessity of light valve gear on a high-speed engine. The extended use of aluminum makes axle weight reduction possible and I would call attention to an axle I have recently designed in which the complete weight of the axle together with brake drums, aluminum disc wheels and tires is about 290 lb. This axle has been driven some 11,000 miles as fast as possible over very bad roads and has demonstrated conclusively its reliability and furthermore the fact that good road holding is just as practicable in a light car as in a heavy one.

Engine size and chassis weight pursue each other in a vicious circle. Because the engine is large it is necessary that the running gear and transmission shall be heavy, and because the latter is heavy it follows that the engine size must be increased to get any desired performance. By tackling the problem of reduction literally from the engine to the whee'ls, the amount of weight which can be saved without sacrificing reliability is surprising. The result is that with a car of the same general type a very much better performance is obtained. If improved performance is not required it is then possible to redesign and maintain the previous performance with a still greater reduction in the weight. One needs experience with the full-size light car to appreciate its economy, reliability, power of acceleration, speed and handiness. The trend of design in general and recent research in particular are along the lines of weight reduction without any sacrifice of essentials.

[1] M S A.E.—Consulting engineer. Cleveland.

Aluminum Pistons

By Frank Jardine[1] and Ferdinand Jehle[1]

Buffalo Section Paper *Illustrated with* Drawings and Chart

It is not the object of this paper to direct attention to the fact that aluminum pistons, due to their lightness, will reduce the inertia forces, thereby decreasing the engine vibration to a minimum and the bearing pressures to a reasonable amount; nor shall we point out that aluminum has a higher thermal conductivity and therefore reduces carbon deposits both above and below the piston head and permits higher compression pressures. These are advantages of aluminum pistons with which all engineers are familiar. We shall only try to point out the developments of aluminum pistons during the last year or so and to make suggestions for their design. This is, possibly, the age of piston invention and it may not be out of place to quote from Professor Diederich's translation of Güldner's Design and Construction of Internal-Combustion Engines, "Less invention more rational design." The internal-combustion engine has possibly both benefited and suffered more at the hands of inventors than any other mechanism, and the piston has received a considerable amount of the energy expended in these directions.

Whenever possible it is well to base a design on something that is known to have worked well before. It is not our intention to suggest that the engineering fraternity attach the same value to precedent as the legal profession, but it is well to follow closely along the design of something which we know has worked well. The aviation engine owes its success, in a large measure, to the aluminum piston. It would therefore be wise in designing an aluminum piston for automobile engines to follow somewhat along the general lines of aviation engine practice, taking into consideration the difference in the characteristics of the two engines. It is interesting to follow through the history of aluminum piston design. The first ones were copies of cast-iron pistons which may not have been based on any particular theory. To gain the maximum advantage from lightness, aluminum pistons were at first made very, very thin, and then many ribs were added in the head to make them strong enough. About this time the Liberty engine piston was designed which eliminated ribs and utilized much heavier sections than had heretofore ever been used in any piston.

The Duties of a Piston

Before discussing the design further let us consider briefly the duties which the piston is called upon to perform. It plays one of the most important parts in transferring a certain percentage of the heat energy in the fuel into mechanical energy and it must also assist to a certain extent in providing a path for some of the waste heat. In the exercise of its first function it is necessary that it reciprocate and to do this with the least amount of disturbance it must be light. Furthermore the gas-engine piston is called upon to do the work which in the steam engine is assigned to three separate parts. It must act as a gas tight plunger and as the piston rod, and it must also work as the crosshead.

In performing the function of plunger it must first of all be gas tight, that is not porous, and must also be of a material which will furnish a good seat for the rings. To perform the duties of a piston rod and a crosshead satisfactorily, it must fit the cylinder with a minimum amount of clearance so that there is very little play when the engine is cold, but with enough clearance so as not to be tight when the engine is hot. In the performance of its second duty, that of providing a path for heat, it is necessary for the piston to be made of a material which is a good thermal conductor. We know that heat enters the piston-head and that a large percentage of this must in time find its way into the water-jacket or cooling fins.

The most important function which the piston performs is that of converting heat into mechanical energy. Providing a path for some of the waste heat is a secondary duty or what we might term "a necessary evil." It is therefore of the utmost importance that the performance of this secondary duty interferes little or none with the performance of the first. Unfortunately up to the present time there has been interference. The heat passing through the piston may cause many undesirable effects such as self-ignition of the charge and excessive expansion of the skirt which necessitates a large clearance when the piston is cold. The first trouble, self-ignition due to a hot piston-head, is eliminated almost entirely by substituting aluminum for cast iron as the piston material. The second, that of clearance, is aggravated by substituting aluminum for cast iron, due to the greater expansion of aluminum.

It has long been recognized that pistons, whether they be made of cast iron or aluminum, must be kept as cool as possible. There has been no agreement among engineers, however, as to how this could best be accomplished. It was thought that if the inside of the piston, particularly the head, were provided with a great number of ribs, much of the heat would be radiated into the inside of the engine and to some degree at least the piston would be cooled by the oil splash. It does not seem reasonable to expect that any great amount of heat can be carried off in this manner. Prof. F. C. Lea, in a paper entitled Aluminum Alloys for Aeroplane Engines which was read before the Royal Aeronautical Society, states:

> It is generally claimed that ribs assist in the cooling of the piston by transmitting heat to the air in the crankcase. The heat-balance sheet of an engine, however, shows that the total amount of heat carried away to the crankcase is comparatively small, and therefore, if the ribs are effective from the point of view of conducting heat from the crown to the skirt they are not effective in conveying heat from the crown to the air in the crankcase. Ribs may be required to strengthen the crown of the piston, especially in those of a greater diameter than 4 in., but it is very doubtful whether a

[1] M.S.A.E.—Engineer, Aluminum Manufactures, Inc., Cleveland.

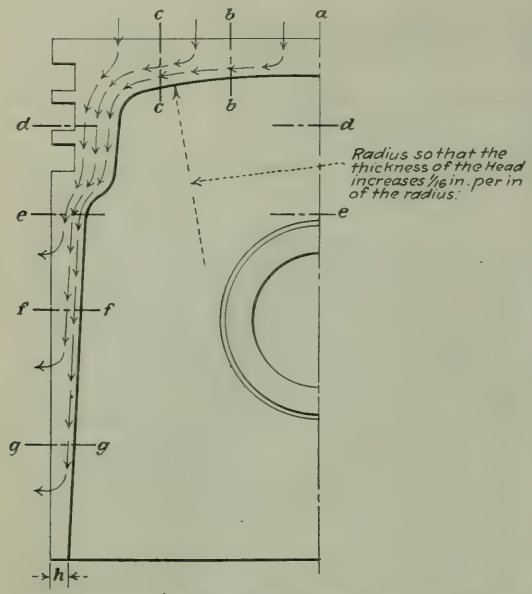


FIG. 1—DIAGRAMMATIC SKETCH OF A PISTON IN WHICH A GOOD PATH IS PROVIDED FOR THE HEAT TO FLOW FROM THE HEAD OF THE PISTON TO THE WATER-JACKET

large number of ribs such as are used in the Hispano piston, are of any value; one must, however, have an open mind upon this question; ribs certainly add to the difficulty of casting. The original sand cast pistons of the Sunbeam Arab engine had six ribs; by making four ribs instead of six, it was found possible to cast these pistons easily in the die, and running tests showed that the four-rib piston had no disadvantages as compared with the six-rib.

Tests which we have made on ribbed pistons and pistons without ribs on a Hall-Scott engine seem to confirm the same results. In these tests a careful record of the temperature of the oil and one of the main bearings was kept. Needless to say the quantity of oil in the crankcase was always kept constant. No difference in the temperature of either the oil or the bearing was detected, which could be attributed to the piston design; although a difference in the temperature of the bearing and the oil could be brought about by a change in the atmospheric temperature.

DESIGNS OF PISTONS

Col. E. J. Hall made the first piston design which came to our attention that had for its object the direction of the heat flow and provision of a good path from the head of the piston to the water-jacket. Fig. 1 is a diagrammatic sketch showing his general theory. The center of the head *a* must be thick enough to insure against the piston getting too hot at this point. Experiments which Colonel Hall made showed that this thickness should be 7 per cent. of the piston diameter. It is evident that the piston-head thickness must increase from the center to the wall in order to keep the temperature gradient at the minimum. A certain amount of heat enters between *a* and *b*, which amount must be conducted through the area *b-b*. Let us assume for the sake of argument that none of this heat is lost by radiation, then the section *c-c* must conduct all of the heat which the section *b-b* transmitted, plus the heat which entered the piston-head from the area included between *b* and *c*. Each section farther removed from the center of the head of the piston must increase somewhat from the previous section. The scheme then was to provide sufficient metal behind the rings so that the great majority of the heat would be conducted through this path into the skirt of the piston and thence to the cylinder rather than through the rings to the cylinder wall. His experiments showed that the annular area of the section behind the rings *d-d* should be equal to one-quarter of the total head area. The section *e-e* which is below the rings should have the same area. In the skirt we meet the opposite condition from that in the head for each consecutive section must conduct less heat. Since some heat is transferred into the water-jacket from *e-f* the section *f-f* should have less area than the section *e-e*. By the same reasoning the section *g-g* need not have as great an area as the section *f-f*. When we get to the end of the piston at *h* all of the heat has been lost to the jacket, and therefore, *h* need have no area and consequently no thickness. Naturally it cannot be made without thickness for mechanical reasons such as strength in operation and for handling in the shop and foundry. The best thing we can do is to make *h* as thin as practicable. A piston of this general design was used in the Liberty engine and, as is well known, operated in a satisfactory manner. At this point it may be well to quote again from Professor Lea's paper,

> For pistons up to a 4-in. diameter a ribless piston with a domelike crown thickened toward the skirt and with a good fillet where the crown and skirt join is all that is required, and even for larger diameters it seems more than probable that such a construction would prove satisfactory. Experiments at the Royal Aircraft Factory have shown that such a piston runs cooler than one of the same weight with ribs.

Various attempts have been made to apply Colonel Hall's aviation piston to automobile engines with the result that while it worked very well from the thermal standpoint it was too heavy. It must be borne in mind that Colonel Hall's work was all done with pistons of about the same size, 15 in. or over, and with aviation engines. Aviation engines produce much more power per cubic inch of displacement and consequently more per square inch of piston-head area than automobile engines. The amount of heat entering the piston-head of an engine is not a function of its diameter but of the square of its diameter. The latter consideration makes it at once apparent that any formula for the head thickness of pistons varying over a great range of sizes cannot be based upon the diameter but must be based on the diameter squared. The total heat developed in the engine must next be taken into consideration; that is, we must take due account of the fact that the automobile engine produces less power per cubic inch of displacement and square inch of piston-head area than the aviation engine.

We shall now try to write a new formula taking these things into consideration. Starting with the Liberty engine operating at 1600 r.p.m. and developing 400 hp. we find that the horsepower per square inch of piston-head area is 400/(19.63 x 12) or 1.7. Letting the head thickness vary with the area of the piston-head and the horsepower developed per square inch of piston-head area, we can write the following formula:

$$T = C_1 D^2 H$$

where

T = Head thickness in inches
D = Piston diameter in inches
H = Horsepower per square inch piston-head area
C_t = A constant

In the Liberty piston $T = 0.375$ and $D = 5.0$. Substituting these values in the formula

$$C_t = T/D^2H$$

we get

$$C_t = 0.0088$$

The wall area will also be a function of the heat entering the piston head. We may express this as follows:

$$A_w = C_wD^2H$$

where

A_w = Wall area in square inches
D = Piston diameter in inches
H = Horsepower per square inch of piston-head area
C_w = A constant

Substituting the values for the Liberty piston of $A_w = 4.91$, $D = 5.00$ and $H = 1.70$ in the formula

$$C_w = A_w/D^2H$$

we get

$$C_w = 0.115$$

In using these formulas the maximum horsepower output of the engine should be used to determine H. It must

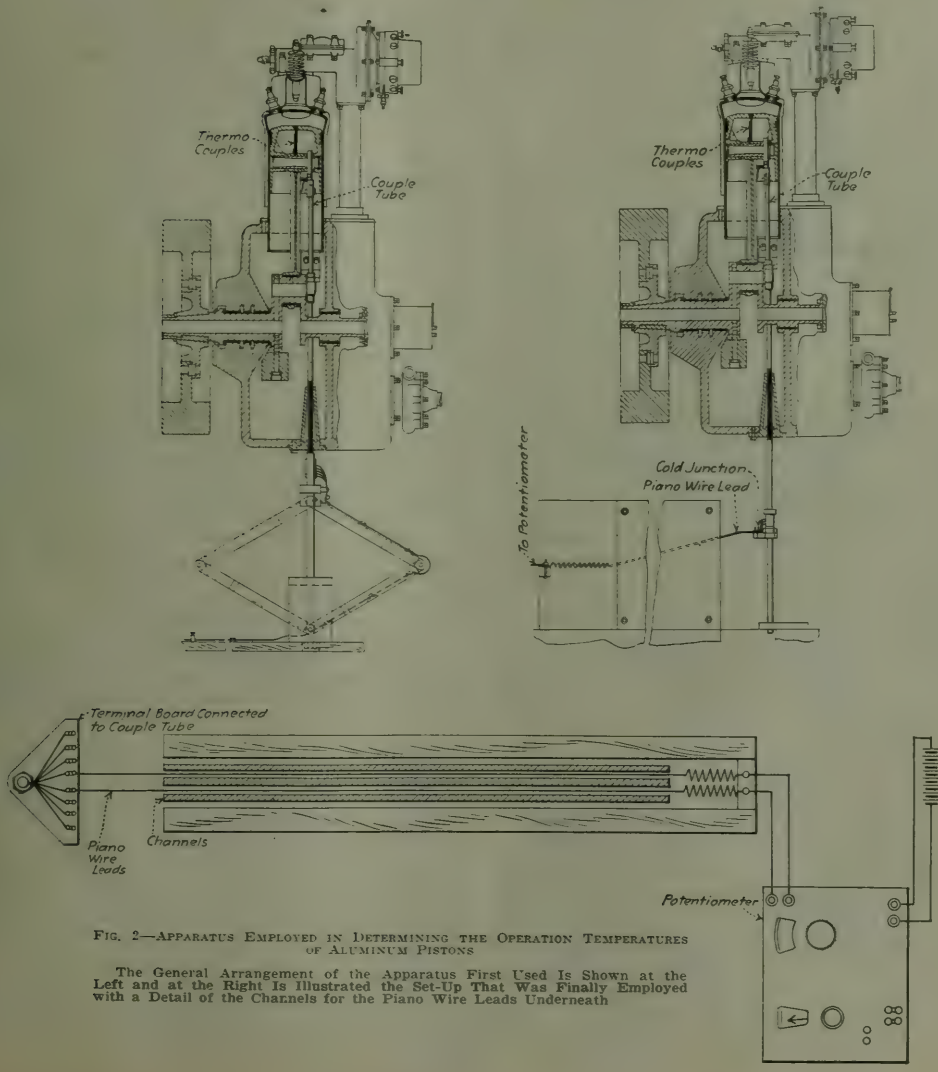


FIG. 2—APPARATUS EMPLOYED IN DETERMINING THE OPERATION TEMPERATURES OF ALUMINUM PISTONS

The General Arrangement of the Apparatus First Used Is Shown at the Left and at the Right Is Illustrated the Set-Up That Was Finally Employed with a Detail of the Channels for the Piano Wire Leads Underneath

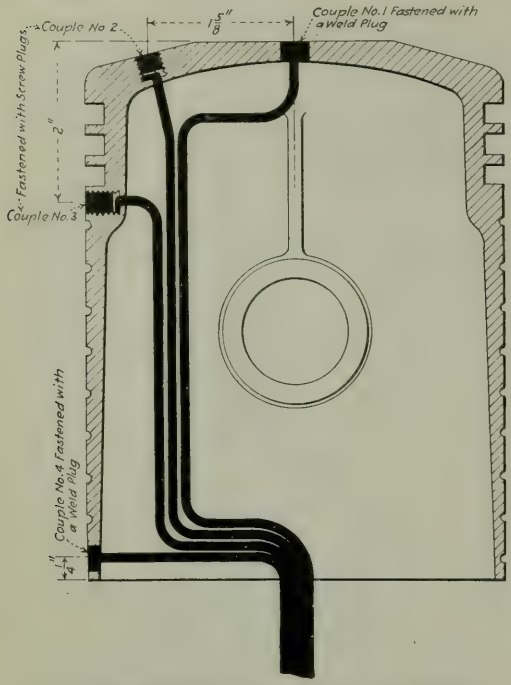


Fig. 3—Arrangement of Thermocouples in the Pistons

also be borne in mind that the minimum thickness of the head or the wall depends on foundry practice and will vary for individual cases. It is therefore best to consult with the foundry on this subject.

Operation Temperatures of Pistons

Several years ago we conceived the idea that much could be learned by actually measuring the temperatures of pistons in operation in an engine. For this purpose a single-cylinder Liberty engine was utilized. It was thought best that some means should be provided for conducting the thermocouples out of the engine without subjecting them to any bending whatever. To accomplish this it was necessary to run a straight tube from the piston down through the crankcase. Due to interference between this tube and the standard crankshaft and connecting-rod these parts had to be redesigned. This required much time, and it was not until about a year after the design was made that the first tests were started.

A general layout of the apparatus in its early stages is shown at the left of Fig. 2. The couples terminated at the cold junction point shown in the diagram and the leads from there to the potentiometer were made of piano wire. This arrangement looked very promising for a while, but it was too heavy and the fastening connecting the piston to the tube was broken. It was then decided to eliminate the pantagraph arrangement and let the piano wire form the connection between the cold junction and the potentiometer unsupported. To eliminate vibration of the wires as much as possible they were placed in narrow channels which permitted motion in only the vertical plane. The upper right portion shows this set up while a more detailed arrangement of the channels is given underneath.

Fig. 3 is a diagram of the pistons showing how the couples were attached and their location. Couple No. 1 is in the center of the head, No. 2 is on the intake side at right angles to the plane of the wrist pin, 1⅝ in. from the center of the head, No. 3 is on the intake side below the rings, 2 in. from the top of the head, and No. 4 is located ¼ in. from the bottom of the skirt, also on the intake side. Several methods were used at different times for fastening the couple to the piston and two are shown in Fig. 3. The first one was to drill a comparatively large hole about ¼ to ⅜ in. in diameter partially through the piston and a small hole the rest of the way. The couple was inserted through the small hole and bent over as shown, and a plug screwed tightly against it. This gave very satisfactory results. The point was raised, however, as to whether or not the plug had a sufficiently good contact with the rest of the piston to insure that it was not hotter than the piston itself. To investigate this point some of the couples were inserted in a similar way to the one outlined except that instead of inserting the screw plug the large hole was closed by welding. This was a rather difficult weld to make but those pistons in which the weld stood up showed no difference in temperatures over those using the screw plug. In all cases the head couples were inserted 1/16 in. from the inside of the piston.

The results of the piston temperature tests given below are not considered as final but are sufficiently conclusive to indicate the temperature distribution in pistons. The first tests were made with a piston designed according to the Hall formula mentioned above. Even the preliminary tests made with these first pistons showed that

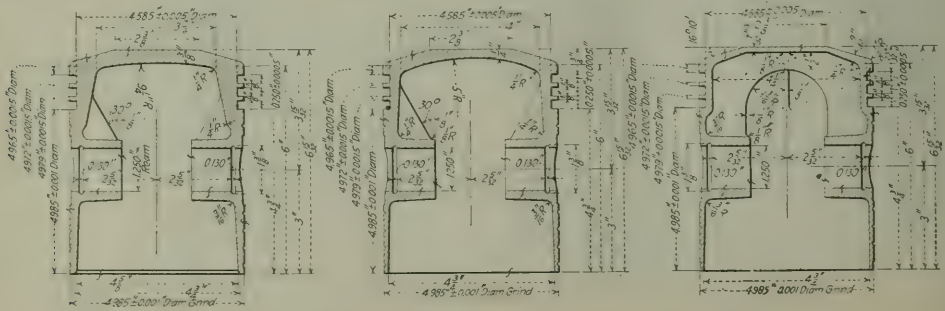


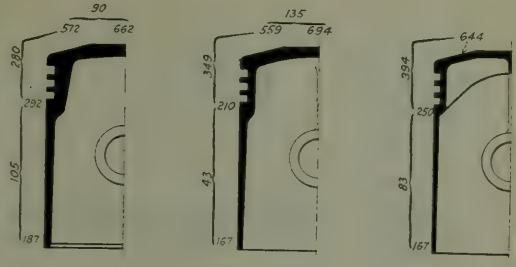
Fig. 4—Sections of the Three Pistons Used in Making the Tests

the heat did not follow the outlined path to the water-jacket. The greatest temperature drop was noted between couples Nos. 2 and 3, that is through the rings, while the drop through the skirt was not as large as that through the ring section. At this point we would like to bring out the similarity between the results obtained by Arthur A. Bull of the Northway Motor & Mfg. Co. and ourselves, although Mr. Bull's work was done on a stationary piston in a water-jacketed cylinder.

It was then decided to make up several pistons of different thicknesses and constructions and note the difference in temperature distribution. Fig. 4 is a set of detail drawings of the pistons that were used. The amount of metal in each one is best expressed by the weights, which are, from left to right, 3.9 lb., 3 lb. and 2.5 lb. Since it was not certain that the apparatus would work at high speeds it was thought best to make all of these tests at 800 r.p.m. or as nearly that speed as possible. Fig. 5 shows the results obtained from these tests on the different pistons, the figures around the outline indicating the temperature at the various points and the drop between them. The average speed of all the tests was 800 r.p.m., the average brake horsepower 13, and the average cooling-water temperature, inlet, 126 deg. fahr. and outlet, 147 deg. fahr. In the piston at the left which was the heaviest, the drop across the rings was 280 deg. fahr. and the drop across the skirt only 105 deg. fahr. In the next lighter piston which is shown in the center the drop across the rings was 349 deg. fahr. and the drop across the skirt 43 deg. fahr. In the lightest piston tested, that at the right, and which incidentally had two cross ribs, the drop across the rings was 394 deg. fahr. and the drop across the skirt was 83 deg. fahr. It is interesting to compare these results and at once it becomes apparent that in spite of any section we can put behind the rings and on the skirt the greatest temperature drop is across the rings. It is therefore very obvious that the origial Hall idea of by-passing the rings is not absolutely correct. It is just as apparent, however, that the amount of metal behind the ring grooves does affect the temperature drop. Comparing the three pistons we find that the drop across the rings is less when more metal is used behind them.

Calculating a wall area based on the power developed by the engine at this speed we would get an area slightly less than the one shown at the right of Fig. 5. It would therefore seem that the formula developed for wall area does not call for too much metal, in fact slightly more would do no harm. The piston mentioned is a trifle on the thin side for mechanical reasons and more metal should be added on that account. The formula for wall area behind the rings should, therefore, for the present at least, be adhered to. The results would seem to indicate, however, that it is not necessary to have as much metal immediately below the rings or in the section *e-e* in Fig. 1. The skirt thickness should therefore be determined largely by casting, machining, and other mechanical requirements.

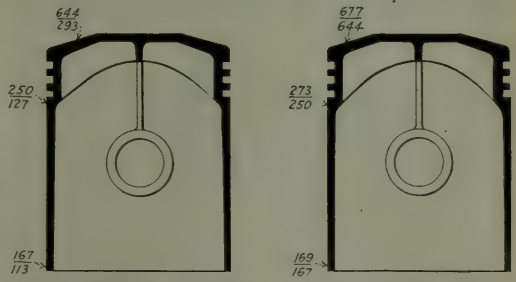
The next interesting point to be considered is the temperature of the head. Unfortunately more trouble was encountered with the couple in the center of the head than with the other couples used and in the one case, that of the piston at the right of Fig. 5, no successful reading was obtained. By comparing the other pistons, however, we can see that some difference can be laid to the thickness of the head. A difference of 32 deg. fahr. was recorded between the center head temperature of the pistons at the left and center. The temperature toward



	Speed, r.p.m.	
800	800	800
	Brake horsepower	
12.9	13.1	13.2
	Inlet Water Temperature, deg. fahr.	
128	126	126
	Outlet Water Temperature, deg. fahr.	
148	145	147

FIG. 5—RESULTS OBTAINED FROM TESTS OF DIFFERENT PISTONS SHOWING HOW VARIATION IN THE DESIGN AFFECTS THE TEMPERATURE IN OPERATION

the side of the head as measured by Couple No. 2 was actually a few degrees higher in the thicker piston. This can be explained in three ways, (*a*) the difference of 12 deg. fahr. is possibly as close as any two pistons of the same design would operate, (*b*) it may show that for the amount of horsepower developed the central piston had a head of sufficient thickness, and that a greater thickness would not be of any benefit, and (*c*) the temperature difference across the thinner head would naturally be greater than that across the thicker head. Couple No. 2, in the lightest piston shown at the right of Fig. 5, however, was 72 deg. fahr. hotter than the similar temperature for the piston at the left. That, without a doubt, is due to the head thickness. According to the formula the first of these two pistons had a head thicker than necessary, but the temperatures obtained would seem to indicate that it was not too thick. If more taper had been used, that is, if the head had been made thicker where it joins the skirt the temperature of 644 deg. fahr. would have been reduced somewhat. Until such time as further work can be done it is wise to adhere to formulas



The Upper Temperature Readings Were Obtained at a Speed of 800 R.P.M. and Brake Horsepower of 13.2 and Inlet Water Temperature of 126 Deg. Fahr. and an Outlet Temperature of 147 Deg. Fahr. The Corresponding Values for the Lower Readings Were 800 R.P.M., 14.0 B. Hp. and 48 and 58 Deg. Fahr.

The Upper Temperature Readings Were Obtained with a Speed of 1000 R.P.M. and 16.2 B. Hp. and the Lower with a Speed of 800 R.P.M. and 13.2 B. Hp. The Inlet Water Temperature Was 126 Deg. Fahr. and the Outlet 147 Deg. Fahr. Throughout

FIG. 6—TEMPERATURE DIFFERENCES DUE TO AT THE LEFT A VARIATION IN COOLING WATER TEMPERATURES AND AT THE RIGHT A CHANGE IN SPEED

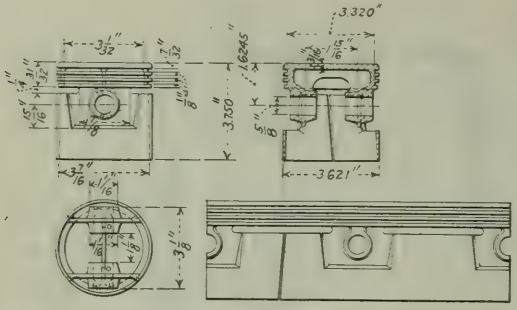


FIG. 7—A PISTON USING A SLOT TO COMPENSATE FOR THE EXPANSION OF THE HEAD

outlined above because passenger-car pistons designed in that way have given good results.

COMMENTS ON THE TESTS

In making these temperature tests other troubles were encountered besides the mechanical workings of the parts. It was discovered that piston temperatures, especially that of the head, were very susceptible to changes in fuel consumption. A sufficient amount of data has not been collected on this subject for presentation in this paper but we can state that it warrants further investigation. All the tests reported herein were made with the same fuel consumption.

It was also discovered that changes in cooling-water temperatures brought about a marked difference in the piston temperatures. The temperature at the lower end of the skirt is dependent, largely, upon the temperature of the cooling water. Sufficient time was not available to go into this problem as thoroughly as would have been desirable but enough data were collected to show the effect of an extreme change in water temperatures as shown at the left of Fig. 6. Unfortunately these tests were made on the piston in which the center head couple was inoperative. Couple No. 2 on the head, while the inlet cooling-water temperature was 126 deg. fahr. and the outlet 147 deg. fahr., indicated a temperature of 644 deg. fahr. When the water temperature was reduced to

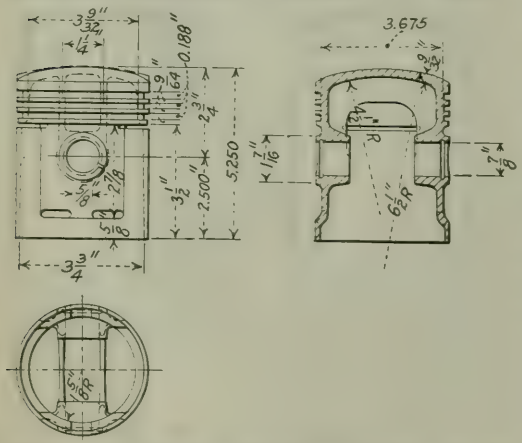


FIG. 8—IN THIS PISTON THE MECHANICAL EXPANSION DUE TO THE HEAD IS TAKEN CARE OF BY RELIEVING THE SIDES

48 deg. fahr. for the inlet, and 58 deg. fahr. for the outlet, this temperature dropped to 293 deg. fahr., that is it dropped 251 deg. Couple No. 3, below the rings, showed a drop of from 250 to 127 deg. fahr., or 123 deg., for the same change in cooling-water temperature. Couple No. 4 at the bottom of the skirt fell from 167 to 113 deg. fahr. It is also interesting to note that the drop across the rings decreased from 394 to 166 deg. fahr. and that across the skirt from 83 to only 14 deg. fahr.

Due to a lack of time it was not possible to study thoroughly the effect of engine speed on the temperature. The right half of Fig. 6 gives the result of one set of tests made at 800 and 1000 r.p.m. The water temperature of both tests was held at 126 deg. fahr. for the inlet, and 147 deg. fahr. for the outlet. The horsepower at 800 r.p.m. was 13.2 and at 1000 r.p.m. it was 16.2 hp. The head temperature was increased from 644 deg. fahr. at 800 r.p.m. to 677 deg. at 1000 r.p.m., an increase of 33 deg. The temperature below the rings was increased from 250 deg. fahr. at 800 r.p.m. to 273 deg. at 1000 r.p.m., an increase of 23 deg. The temperature of the lower end of the skirt remained the same; the increase of 2 deg. from 167 to 169 deg. is not outside the limits of error. Judging from the results so far obtained the speed has little effect on the skirt temperature. Before stating this definitely more tests should be run and such tests are contemplated.

CLEARANCE REQUIRED

As shown by the tests much of the heat leaves through the rings. The temperature immediately below the rings is at times several hundred degrees lower than the head temperature. Since thermal expansion is a function of the temperature it would seem, offhand, that this state of affairs would be ideal. We know, however, that the clearance required for aluminum pistons is much in excess of that necessitated by skirt temperatures. There can be only one explanation of this and that is, that the hotter piston head will cause a mechanical expansion of the skirt in addition to the thermal expansion due to its temperature. The force set up in a structure due to its temperature is really enormous, as a simple calculation will show.

$$\text{Modulus} = \text{Unit force} \div \text{Unit deformation}$$

then

$$\text{Unit force} = \text{Modulus} \times \text{Unit deformation}$$

Modulus for aluminum = 10,000,000

Unit deformation for 1 deg. fahr. rise = 0.000012 in.

Substituting

$$\text{Unit force} = 10{,}000{,}000 \times 0.000012$$
$$= 120 \text{ lb. per sq. in. per deg. fahr.}$$

Bearing in mind that the difference between the skirt and head temperatures is at times several hundred degrees we can get some idea of the magnitude of this force. There can, therefore, be no question that the expansion of the head is accountable for much of the clearance which must be given to the skirt of a piston.

If the skirt could be entirely separated from the head the clearance could be greatly reduced. It is not practical, however, to separate the head entirely but it can be separated from certain portions of the skirt so as to relieve the skirt of mechanical expansion in certain directions. The most reasonable place to reduce the expansion in this manner is across the thrust faces. A saw slot immediately below the lower ring on both the thrust faces will bring about this condition. The mechanical expansion of the skirt in the direction of the axis of the

wrist pin will remain unaltered and some means must be provided for making this expansion harmless. This can be done by relieving these faces for their entire length or providing some flexibility by a slot. Both methods have been used and have given satisfaction. By separating the skirt from the head we eliminate mechanical expansion in one plane, that is across the thrust faces. Supposing we consider a piston with its head and skirt separated as just mentioned, running under conditions such as were shown in some of the temperature charts, with an average head temperature of 600 deg. fahr., a rise of 530 deg. above room temperature, the expansion of the head would be 0.032. The skirt temperature in this same test was 210 deg. fahr., a rise of 140 deg. above room temperature. This on a 5-in. piston gives an expansion of 0.0085 in. The mean cylinder-wall temperature is the average between the piston-skirt temperature and the cooling water, that is 178 deg. fahr., 108-deg. rise over the room temperature. This would give a cylinder-wall expansion of 0.003 in. The clearance necessary should then be the difference between the piston expansion and the cylinder expansion, which in this case is 0.005 in. This would give us no clearance for an oil film and the piston would seize. Tests which we have made prove that 0.005 in. is enough for a piston of this description running up to 1600 r.p.m. at which the skirt temperature is undoubtedly somewhat higher than at 800 r.p.m. The clearance which we know is necessary for the piston is less than the temperature would seem to indicate. This can be explained in the following way: The expansion of the head is acting on that portion of the piston skirt which is not separated from the head by slots and is imparting to it a mechanical expansion in addition to the thermal expansion. If a circle is expanded only along one diameter it will have to contract along the diameter at right angles to it, that is the circle will be changed into an ellipse by shortening one of its axes and lengthening the other. The mechanical expansion along the axis of the wrist pin has been made harmless by either relieving the piston at the ends of the wrist pin or by giving it flexibility by a vertical slot.

Fig. 7 shows a piston which makes use of the flexibility by means of a slot to correct for head expansion. This type is in use in the Maxwell car. Fig. 8 shows a piston in which the head is separated from the skirt on the thrust faces and the mechanical expansion due to the head is taken care of by relieving the sides as shown. This type is in successful operation in Northway engines. In making slots it should not be overlooked that these should be made as wide as possible so as to allow a free passage of the oil back into the crankcase. In providing

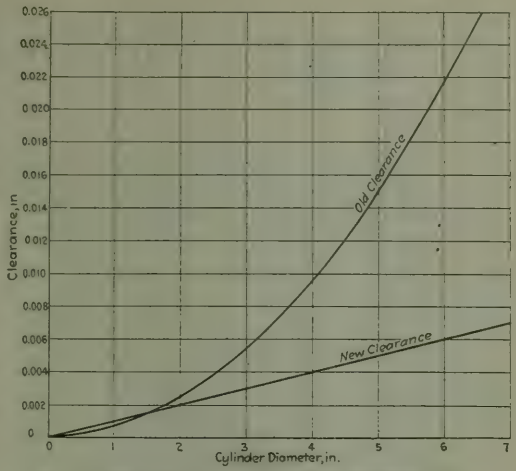


FIG. 9—COMPARISON OF THE CLEARANCE FORMERLY USED ON ALUMINUM PISTONS AND THAT NOW PREVAILING

a relief on the sides this should be of ample depth. Holes of a large size or preferably a short slot at the bottom of the relief should be provided so that oil accumulated in the relief can pass away easily and quickly.

The successful operation of pistons is measured by the minimum clearance necessary for satisfactory performance. The progress of aluminum pistons within the last few months can be shown best by comparing the clearance curves in use now with those in use several months ago. Fig. 9 shows these two curves, both of which are based on experiments. The top curve shows the clearance necessary for pistons of the old conventional type and the lower the clearance necessary for the types just mentioned.

It is, of course, impossible to lay down this curve as a definite law. Engine temperatures undoubtedly depend on engine design and piston temperatures depend upon piston clearance. While these curves were determined from actual practice the characteristics of all engines may not be the same and some variation might be found necessary. The actual clearance required can be determined only by tests in each case but the clearance on the curve represents a safe starting point for these tests. In the past aluminum pistons have shown certain faults but present practice indicates that these faults were faults of design and not faults of alloys.

AGRICULTURE IN CHINA

NEXT to America China is the greatest agricultural nation on the face of the globe. China's tremendous population of 400,000,000 souls is intimately and closely connected with the soil. Of China's $1,000,000,000 foreign trade in 1919 more than 80 per cent consisted of agricultural products or products which were all more or less closely associated with some form of agriculture.

In China farming is on a gardening basis. Practically all Chinese farmers own their land, but they do not own much land. In the densely populated coastal plain and Yangstze valley, an average Chinese farm is about the size of an American acre and this is probably a liberal estimate. Cultivation is intensive and it is not unusual to see three or four crops such as cotton, beans, cabbage and corn all growing on the same patch of ground, not separate plots, but "between the rows."

Although the Chinese farmers have worked out their own methods of land fertilization that have kept their soil fertile for 4000 years, they have not developed their farming implements. Chinese plows, hoes, rakes and harvesting implements are of the vintage of the year one or possibly, to be more exact, the pyramids of Egypt. The beast of burden in south and central China is the carabao or water-buffalo. In north China, Manchuria and Mongolia it is the mule, pony and sometimes the ox and camel.—J. B. Powell in *Farm Implement News.*

Automobile Body Construction

By P. E. Stone[1]

Boston Section Paper

AUTOMOBILE body construction is about to enter upon an advanced state of development. Sales depend upon the appearance and comfort of motor cars, chassis are becoming better standardized and the popularity of the enclosed type of automobile body is growing. This paper is devoted more especially to enclosed body construction, with the object of creating a closer relation between the chassis and the body designer, from the viewpoint of an automotive body constructor.

Few books have been written on the strength and desirability of materials for an automobile body and its members, and they are not of great value. I shall enumerate, therefore, what are probably the most important materials that enter into the construction of the enclosed type of body. The different kinds of wood used include ash, yellow poplar which is commonly misnamed white wood, birch, maple and the cheaper kinds, depending upon the grade of body that is to be built. Aluminum of Nos. 14, 16 and 18, B. & S. gage is employed; this is 98 per cent pure aluminum, one-half hard. Steel, of automobile body drawing ductility and of Nos. 20, 22 and 24, B. & S. gage, is utilized. Very little long terne or lead-coated steel is used for body purposes. Cast aluminum is sometimes used. Plywood and composition material are the most important of the less used materials. Plywood was used considerably in automobile body roof construction several years ago.

The most important of the glues is hide glue, some of which is treated for moisture proofing. Others are casein, blood-albumen and fish glues. The casein and blood-albumen glues are considered the best, but as yet they are not entirely dependable and must be mixed and used by an expert.

The Proper Seasoning of Wood

The piling and drying of lumber is especially important in connection with body construction. The lumber should be piled with great care from the time it is green until it goes into the final assembly of the body. Lumber often is piled in a damp place, or upon an uneven foundation, or is not properly spaced. If piled solidly, an unevenness often develops and a twist or wind is given to the board. This results later in a permanent set which can be remedied only by properly steaming the piece in a dry kiln at additional expense. With proper care used in piling and proper foundations and spacers of equal thickness on each tier, one placed directly above the other, a great saving is effected and a better product is secured. If boards have a permanent set that has not been relieved, they will be undersize when dressed or, if sprung into shape, a twist will eventually result in the member in which such a board is used.

Let us consider the methods of seasoning wood. Lumber salesmen will say that air-dried lumber is bone dry. In certain parts of Mexico, air-dried lumber means lumber that has come to the condition of the surrounding air. It will show a moisture content of about 5 per cent by weight. Again, in certain parts of the United States, air-dried lumber will contain 20 per cent of moisture. Therefore, if an automobile body which has been manufactured of air-dried lumber in a moist climate is sent to some locality in a dry climate, the lumber will shrink from 3 to 5 per cent across the grain. Hence, any bolts which have been used in its construction probably could be tightened one or two turns, depending upon the thickness of the material and the thread size. As soon as a bolt becomes loose, it causes a creak in the body, paint cracking and chipping, and other general troubles.

The dry kilning of lumber probably is the most important phase of lumber seasoning and it is also just as delicate an operation as the hardening of steel. Very little is known generally about dry kilning. When lumber is properly dry kilned and is not killed during the process, it is probably stronger and of a more uniform moisture content than lumber that has been air dried in the pile. After considerable experience in manufacturing airplane propellers, I think that lumber dried to a moisture content of from 8 to 10 per cent will give the best results for all conditions of atmosphere, because the moisture which is absorbed after the wood has once been dried is not so detrimental as the shrinkage. Probably, only a small percentage of the dry kilns used in automobile-body building plants could pass the Government specifications for dry kilning. Very many of the automobile body builders are still using the old fashioned hot or dry box. A pamphlet entitled Information for Inspectors of Airplane Wood, prepared at the Forest Products Laboratory of the United States Department of Agriculture, is available for those who are interested in the proper drying of lumber.

Metal Bodies and Construction Features

All-metal or steel bodies are made only for open-car types. Very little all-metal or steel construction has been developed as yet for enclosed bodies, owing to the fact that many things, such as tacking rails for upholstery and window regulators, are required which necessitate using wood. Further, enclosed bodies have not been built in large enough quantities to warrant the expensive dies which would be necessary for all-metal construction.

With regard to the actual construction of automobile bodies, the day has past when the woodworker in the body shop was given an outline draft, selected the stock from the lumber pile, made his own patterns, located the mortises and tenons and used the band saw, planer and other machines, completing the whole process himself. Today, the draft must be made so that the mill can get out the stock without seeing the draft as a unit; also, the shapes of each piece must be changed sufficiently to allow the mill machinery to reproduce it without too many separate operations and set-ups. These pieces must be constructed so that they can be assembled into units, such as backs, quarters, doors and roofs, and can finally be put together without a great amount of fitting. In fact, the draft as a whole does not leave the draft, pattern, layout and dressing-box rooms. Each man in the shop does only his own part. Where only two men touched a body in the body shop under former condi-

[1] M.S.A.E.—J. B. Judkins Co., Merrimac, Mass.

tions, 25, 50 or more, may participate in its construction at present. This specialized construction is and has been developing many new machines for the mill. It also places a certain handicap upon designing. The methods of construction have been changed completely within the past 10 years.

In body construction, the draftsmen should have not only careful and accurate measurements of the chassis, but they should know the maximum amount of deflection, plus and minus, of the chassis frame from front to rear. They should know also the amount of wind or twist of the chassis. Neither of these factors have ever been defined, to my knowledge, but the construction has to be made so as to take care of both. This lack of necessary information has caused much trouble. It has produced body creaks, rattling doors, excessive up-and-down play of the doors and the opening of body seams.

Chassis Deflection

When you ride in a car with an open body with the top raised and are badly jolted you sometimes hear the material of the top snap. This is good proof of whether a chassis frame twists or deflects. The top first loosens and then snaps tight. This is more in evidence when the top is of the old cape type. Also, the doors move up and down. In a rigidly constructed body with roof rail, the body must withstand all of these strains. Again, the chassis designer fixes the steering column both to the chassis and to the instrument board in the body, which is placed 24 to 36 in. further back on the chassis frame. Strike a rut and the frame deflects; the instrument board creaks and twists, or the steering column bends, otherwise there must be a very rigid construction that ties these three parts together. If the chassis frame deflects down and then up, a tension or a compression force is set up in the roof rail because the center of bending is either above or below the frame. In most of the slanted fronts there is a triangular support which does not allow the front pillars to bend. This either directs all the thrust to the back of the body or transfers the thrust down into the cowl. It is more than likely that this thrust causes many cowls and front pillars to give trouble above the belt on coupés, sedans and four-door inside-drive bodies.

In fastening a body to a chassis frame, sometimes the body sills are placed directly on the frame. The body may be fastened on angles or lugs, three or four to a side, and from 2 to 4 in. from the outside of the frame. This introduces a third strain on the body, as there is a slight twist introduced into the side member of the frame which results in a twist of the body sills. The argument in favor of this method is that it eliminates the squeak between the body sill and the chassis frame, but the mounting of the sill directly above and on the frame, with proper separating material, will usually give the best results. These are a few of the difficulties, but they are beyond the control of the body engineer.

With regard to the constructor's difficulties, let us first consider the body as a mass, concentrated at one point. Such a point would be located from one-half to three-quarters of the length of the wheelbase from the front and from 36 to 60 in. from the ground, dependent upon the style, size and shape of the body. If the front wheel strikes an obstruction, although part of the shock is absorbed by the rubber tires and part by the chassis springs, there is still the inertia of the body as a unit to overcome. Since the force is dependent upon the speed as well as upon the mass, enormous strains are exerted in the joints of the body at high speeds on some rough roads. This force can be divided into vertical and horizontal components. The horizontal component is the one which produces serious effects upon the body construction. The cowl and wind shield are at the front and there is very slight chance for heavy or rigid construction, owing to the fact that the driver must have as much unobstructed vision as is possible; also, the pillars, from the belt up, tend to bend and they must overcome a large part of this horizontal force. If it is a slanted-front construction of a rigid type, this force is transmitted down into the cowl and causes squeaks, rattles and cracked panels.

One way to lessen this horizontal force is to lower the center of the mass and make the roof construction as light in weight as possible. On straight front bodies, it is a good method to taper the pillars from 1 to 3 in. from the belt rail up. On slanted front bodies it is good practice to provide a rigid construction and have a member following the angle of the wind shield to the chassis frame as near as possible. It is possible to have the front of the body strong enough to withstand this horizontal force, and the reaction may be transmitted to the back of the body and cause open joints.

Development Possibilities

There is considerable opportunity for development along the following lines. Springs should be designed to allow the same elasticity for two as for seven passengers. This would result in less strain on the body. Hard, stiff springs shake and jar body joints. The frame might possibly be designed with a subframe of the full body width at the outside of the sills, cross-braced not only to support the transmission but to eliminate as much twist and wind as possible. At some future time we may build the body and the frame as a unit, possibly using I-beams instead of channel irons.

The progress that is being made in automobile body construction includes a heavier cowl construction, together with the use of heavier gage aluminum and more spot-welding or reinforcements. In the larger body plants great care is being used in drying lumber. Roofs are being constructed that are lighter in weight and of materials that will cause less drumming, or resonance. Slat construction is used in many different forms; it is covered with woven material or leather. The trouble found with plywood, when used for roof construction, was due to the fact that there was a large amount of resonance caused by the movement of the wheels on the road, which tired the ear drums of the passengers. Metal roofs were subject to the same rumble and it developed also that extreme heat would cause a slight expansion of the metal and allow the roof to rattle. Much experimenting is being done with different types of cushion spring construction. Curtain rollers have been improved, but locks, door bumpers, door strikers and the like, have not advanced to any great extent since the construction of automobiles began, although some slight improvements have been made.

I think that body construction will not be changed radically until either the basic type of design or shape is transformed or there is a firmer foundation to build upon. Today, all types and styles of body, from the two-passenger open-type to the seven-passenger enclosed-type bodies, are built upon the same foundation base. When we have different frames, and this will be only through evolution, much of the weight, rattle and noise of the enclosed automobile body will be eliminated.

The Discussion

E. W. M. Bailey:—I wish to call the attention of automotive engineers, especially chassis men and the men who are not body builders, to the twisting effect of the chassis upon the body. I have had some experience in building automobile bodies, and I cannot see why any enclosed body does not go to pieces. I have had trouble with some that did go to pieces. In one case we insisted that the chassis maker use a deeper frame because the deflection was so great. There has been no real remedy suggested.

I ask automotive engineers, salesmen and automobile men generally, not to be too conventional. When the horseless carriages came out they were very unconventional. When the engineer came out with a new idea, it was accepted if it was right, no matter how it differed from the conventional. But, my father said that in the days of the coach and carriage builders they were not allowed to do unconventional things. Our American coach builders really copied the designs of the French and English, which were very heavy. No man was allowed to build a light coach body of the enclosed type. The buggy builder, however, designed a purely American vehicle and it was made to carry ten times the passenger or vehicle weight that the coach carried.

In enclosed body building the chassis must twist. This means that the body must give or else the body must help support the chassis. Both things happen in practice. If the chassis sill is bolted down throughout the whole length of the frame, it undoubtedly strengthens the frame to some extent.

Weight is a serious thing for the automotive engineer. These things are all related to each other. The weight of a limousine body might be as stated from 1500 to 2000 lb., but that is a little heavy according to my experience. Even 1200 or 1500 lb. is considerable weight to carry around. I have had experience with the electric automobile, where one could absolutely measure the power required to move the car. Our power was cheaper than gasoline, but we naturally wanted to economize it. With voltmeters and ammeters we could measure the power accurately. If a difference of 10 to 15 lb. would show in a 2000-lb. electric car as it did in our tests, it certainly affects the performance of a gasoline car.

In the matter of the chassis and the body twist, we must either arrange some kind of three-point suspension or a separate frame, so that the body need not carry the chassis frame; or, we must devise a construction so that the body can move with the chassis without wrenching itself. Either of those things is possible if we disregard conventional ideas. If an enclosed body were constructed in a very different way so that these things could be done, probably it would be termed a freak. The construction of the enclosed body is highly conventionalized. There are some 350 pieces of wood in the frame of a limousine. Every one of those pieces is named; the sill, the pillar, the rails, and even the minor pieces all have a name or are described by location. If a body is to be built as suggested, that conventional construction must be eliminated and I think it can be done.

In my electric car propositions, we made a phaeton body, an open phaeton like the horse-drawn phaetons that were very common at one time. We made a bentwood body that was 4 in. wider than any other and that weighed less than any of the others. It weighed less than 30 lb. and there was no other body that weighed less than 130 lb. If it could be done in that case, it can be done in the enclosed body through the use of laminated wood or plywood; not used as a covering over of the conventional frame, but with an entire change of the frame. My father was, I think, the pioneer in the use of laminated panels in vehicles, the first one being of basswood, with linen between. Previous to that he made rotary-cut panels with a band saw. He sawed a log endwise in a spiral curve to the center, and then steamed the product and straightened it out. By this method we could make much thicker panels. We could cut ½-in. panels and straighten them out without causing checks on the outside. We could use a hard wood such as ash, oak or walnut, and get out panels 40 ft. long and 4 ft. wide that were all quartered grain. I have used plywood a long time. If the body is designed to utilize the strength of the plywood rather than the frame and we are allowed to do some other unconventional things, I believe that the weight of the enclosed body can be reduced certainly 50 per cent. I think we could reduce its weight 60 per cent or even more. If we could eliminate 500 or 600 lb. of weight that the chassis must support, think what this would mean in improved car performance. If 100 lb. of weight will show in the power required to move an electric car, certainly a saving of 500 to 800 lb. is of value to automotive engineers in gasoline propelled cars.

Regarding the curing of wood and the statement that a moisture content of 10 per cent is about the standard, Mr. Stone spoke about the effect of wood swelling and shrinking afterward when fastened. I have kiln-dried some millions of board feet of wood for bodies and have had most of the trouble with the wood in the factory. Some factory buildings are very dry. From the time the ground freezes until spring their atmosphere is absolutely dry. In the wholesale production of enclosed bodies it is necessary to pile up many thousands of pieces of body frame ahead of the bench worker who assembles the parts. If they were not very dry, that could not be done. I have dried most lumber down to 2 or 3 per cent of moisture content. With good apparatus and skilled men in charge of it the kilns will do that. Then we took the pieces into the shop and, after being band-sawed they would have time to come to the humidity of the factory. We never had any trouble on that score. For the benefit of body makers who work in smaller quantities, I would say that in the horse-drawn vehicle days, where we handled many thousands of pieces, we never kiln-dried a plank in our own factory. We blocked it out first to the rough dimensions, dried it almost to absolute dryness, brought it into the factory and let it rest there until it reached the humidity of the shop. It would do that in a week, in ordinary commercial quantities. You can dry a stick very much quicker and with less care than you can a plank or board. Band-sawed air-dried lumber can be dried successfully in a hot kiln; some moisture can be supplied if one pleases, but there is no apparent trouble from it at all in the small pieces. One cannot get case-hardening in a piece as small as a pillar; perhaps a sill would require some different treatment, but from a pillar down there is no trouble in drying ordinary quantities.

Chairman R. E. Northway:—It would appear that we must have either resilient bodies or three-point suspension frames.

P. E. Stone:—As to the weight of bodies, when I mentioned 1500 or 2000 lb. to the body I meant the weight as ordinarily equipped, with chassis equipment, tools and passengers. I spoke of 2000 lb. because that is really the weight which the body stands. The average weight of an automobile enclosed body today will vary from 700 to

1200 lb. and possibly one make of body would weigh about 1300 lb. without passengers. The statement is true about drying lumber to sub-normal shop conditions. Dry the lumber too low and let it come up in moisture content, rather than begin with too much moisture and lower it in the shop. When lumber is shrinking it checks; when it is absorbing moisture it does not check. Many large body-building plants are introducing thermostatic control to take care of the humidity in the winter. This is true also in furniture shops.

I have had considerable experience in drying panels. Plywood, when using the glue spreader, should be dried to a moisture content of about 5 per cent before the glue is applied; say 3 to 5 per cent for the core and shell. When it is finished and comes out of the dry kiln for the last time it has from 8 to 15 per cent of moisture; my experience has been to keep the dry kiln below 100 deg. fahr. temperature for best results, because there is less internal strain in the cores. If the temperature is raised too much with low humidities, there is a certain expansion of the core, which is laid opposite the grain of the shell; lower temperatures and rapid circulation of air will give very good results. Thicker panels should not be taken out of the dry kilns until the temperature of the kiln and the plywood has come down to that of the room.

Great trouble is experienced with veneer in roof construction. Formerly there were more veneer than plywood roofs. The shell and core were of different thicknesses in the old automobile body roofs. Several years ago when the dome shapes with sweeps from front to back began to be used, roofs were manufactured only by one or two companies in the United States who used a mold and built the plywood up to fit the double curvature from front to back with the proper sweep. These roofs came practically to shape, otherwise checking would have resulted. We covered these roofs with canvas and painted them. The great trouble with plywood in automobile body construction is to moisture proof both sides. If it is treated with anything to keep the moisture out, a good glue joint cannot be obtained. That is the only difficulty with plywood. If one can nail or screw it on, it is all right. But if a glue joint up against a pillar or something like that is wanted, there is difficulty in keeping the moisture away from both sides of the plywood. If the moisture gets at it, trouble results.

WILLIAM J. BAIN:—The statement that ox blood and casein glues had to be used by experts, applied several years ago, but it is really not true today. Casein glues really gained their prestige in the war, as was true of many other things. Casein and blood albumen are about the oldest adhesives known and are not a new discovery as many people think today. Ask any old fellow that has served as an apprentice in Europe, if he has ever used a "pot-cheese glue" for gluing outside work. Very likely he will say he has. This pot-cheese glue was a casein glue.

When the casein glues were first introduced into this country, they were shipped to the manufacturers in two parts. The manufacturer received the prepared casein and the other ingredients, and was given a formula for their mixing. He had a man in the plant who did nothing but mix this casein glue. Generally this man prepared much more glue than was required for the work on hand, and as the glue would not stand up for more than 2 or 3 hr., he would have to throw away about 50 per cent of the mixture, causing a loss of both time and material. This was a great objection to the casein glues. But since then, the laboratories have been studying the problem, and they have now improved the casein glues so that the ordinary man in the shop can use them just as well as he uses the hide or other glues. About the beginning of the war the glue was put out in the form of a white powder; it was necessary only to add the proper proportion of water, agitate it for a few minutes and allow it to stand about 12 min. In about 15 min. after this powder is mixed with the water it is ready for use. It need not be used immediately, as the glue will stand in proper solution for about 12 hr. under ordinary conditions.

For all practical and commercial purposes the casein glues are waterproof and will stand up under any condition that they will encounter in the commercial line. An old foreman told me that he had used casein glue 40 years ago in Austria. He made tables that stood out in the open air in the Royal Gardens. Several years ago he went back there and found that those tables were just as good as the day they were made. Actual tests offer further proofs. Take a panel for instance, lay it up with casein glue, and allow it to dry for 48 hr. until the glue has arrived at its maximum set, and has attained its full waterproof qualities. The panel can then be boiled for 10 to 12 hr. and there will be absolutely no separation. It can be soaked in water indefinitely. I have soaked such panels until they have become green with mold. I could then twist such a panel into a spiral and there was no separation. A panel can be subjected to sufficient heat to char the wood, and the joints will not open up; in fact the joints are moisture proof and heat resistant at the same time.

For practical use in the factory the advantages of casein glue over other glues are numerous, in that they are waterproof and heat resistant, and are more economical to use in every way, both from price standpoint and spreading capacity. It covers from 40 per cent to 100 per cent greater space to the pound than hide glue. It is more easily prepared, being mixed cold and applied cold, and within 15 min. after mixing one can begin spreading the panels. There is no other glue on the market that can be prepared and used as quickly as this. Another feature is that the use of hot cauls and steam boxes is eliminated, and the glue room need only be kept at the regular temperature of the balance of the factory, say about 70 deg. fahr., and proper gluing can be done and the desired results obtained.

Mr. Stone referred to molded plywood tops. I have seen such tops molded, and these tops have been used for years, and they were put together with casein glue. Gluing operations in the factory did not have to be changed, except to eliminate heat as referred to before. The only special apparatus needed is a rotary mixer that will prepare the glue fast enough.

Various grades of casein glues are manufactured: there is a special grade for joint work, and another for veneer work. These special glues stay in solution for about 12 hr. A third grade used for veneer work is a glue that will take about 2½ lb. of water to every pound of glue; what is left at the end of the day is kept and mixed with the fresh batch next morning, so there is no loss. This is a new development since the war.

MR. STONE:—What is the rate of deterioration of the casein glues? What makes some casein glues soluble in water?

MR. BAIN:—The deterioration of casein glues is only relative, as glue mixed at 8.00 a. m. can be used until 6.00 p. m., but the next morning one would find an insoluble

mess in the glue pot which greatly resembled a custard.

The glues on the market at present include vegetable, fish, hide, blood-albumen and casein glues. Hide, vegetable and fish glues set by the evaporation of the moisture that is in them. Humidity or dampness causes them to dissolve again because they are just dried by the evaporation of their moisture content, but undergo no chemical change. With casein glue, as soon as the powder and the water are put together, a chemical action begins. This chemical action is very perceptible within the first 15 min. of mixing. The original mixture looks very much like a cooked cereal. After 15 min. its nature changes, and it runs in a free flowing liquid, very smooth and very similar to a heavy cream. The chemical action continues until the glue is absolutely hard.

In contrast to the hide glues, the older a casein glue joint becomes, the harder it becomes. The casein glue joint is also stronger with increased age. We have proved this by laying aside joints for 3 or 4 years and breaking them on a testing machine, in comparison with joints 48 hr. to 6 weeks old. The older joints showed the higher percentage of strength.

MR. STONE:—Some casein glues are moisture proof and some will dissolve the first time they are touched with water. What chemical action is lacking? Is it not true that one cannot be absolutely sure of the present casein glues?

MR. BAIN:—I can speak only from the standpoint of one casein glue that I have worked with and tested. I have samples that I have baked, boiled, soaked in cold water and all that. I cannot detect an opening on the joint. When I say that the casein glue I am talking about is absolutely waterproof, I mean that it is highly water resistant for commercial purposes; that is, if a panel is glued up and left to dry for 48 hr., it will not come apart within 2 or 3 hr. after being thrown into a tank of water, and will also undergo any of the tests mentioned before.

MR. STONE:—Are you sure that every batch of casein glue will be equal and alike?

MR. BAIN:—The firm I refer to has been manufacturing waterproof glue for 20 years. It manufactures its own casein, and has a laboratory in which everything that goes through for use in the glue is carefully watched and tested. Being manufactured according to a chemical formula, the casein glues are as consistent as they possibly can be, and can be depended upon. This consistency has been found in shipments of casein glues, which cannot be said of hide or other glues. As to what makes some casein glue water resistant and others not, that is a matter of chemistry and I do not know.

Casein waterproof glues when used in conjunction with plywood for automobile construction, will bring the cost down to a practical figure, and will tend to eliminate the shrinking and opening up of the joints, and can be used with a greater margin of safety on panel work, than vegetable or other glues. The blood-albumen glue panels are more waterproof than those of casein glue, but are high in relative cost, and are almost prohibitive for exclusive use in general body building.

Regarding the length of panels and the size of panels that can be rotary cut, this work is limited only by the length of the lathe and the thickness of the log. I have seen an oak log peeled, and the veneer ran off fully 125 ft. in length. This sheet was broken into 25-ft. lengths, and these laid over one another. They were then carried on an automatic conveyor to the slicer, where they were cut to the size of the panel desired.

MR. BAILEY:—To automobile body builders, this matter of slightly more or less waterproofness of glue is splitting it too fine. I can find sleighs with laminated panels made with hide glue that have been in use for 30 years and that are all standing up. Bodies are painted inside and out. If they are not so painted a waterproof glue is better, but if they are properly painted they will stand up anyway. We have glued thousands of panels with hide glue, using no screws or other fastening, and in quantities of them 10 years old the panels are not warped.

MR. STONE:—When I first started to build automobile bodies we were making them entirely of wood. We thought we could not make a back with a side panel and not have a molded covered joint. We have found out that this can be done. It was done with hide glues and on exposed joints; those hide glue joints are still standing up.

MR. BAILEY:—Is that under a good paint?

MR. STONE:—Yes.

CHAIRMAN NORTHWAY:—We need more definite information as to how to design and construct automobile bodies to meet road conditions and lighten the weight of the car.

C. H. METZ:—The problem is how to combine the body with the chassis. The two features which must be considered are the deflection of the frame member owing to the weight and strain placed upon it, and the twist that it is subject to on account of the unevenness of the road surface. I think it is not possible or desirable to build a frame sufficiently rigid so that all the twist can be eliminated. We eliminate the deflection caused by the weight, by building the frame section much deeper. I think the tendency is in that direction. A number of cars are being built now with frame sides 8 to 10 in. deep, which takes care of that situation very effectively.

The twist in the frame is a considerable problem and I think the frame is not the only member that must be considered in solving it. The tires take care of it to some extent. That matter is being solved in the right direction by using larger tires and ones that are more flexible. Tires are depressed by the amount of weight that is placed on them. An unevenness in the road causes the tire that goes into it to be relieved of some of the weight and the tire on the opposite side has an extra burden. Some of that unevenness is taken care of by the tire. Another member that takes care of more of this unevenness is the spring. Unfortunately, springs do not have a sufficient horizontal range to take care of all of the unevenness. There is opportunity for an improvement in springs, so that when one wheel goes into a hole the part that the tire cannot take care of will be taken care of to a considerable extent by the spring. In an extreme case, the frame will have to be flexible to some extent to take care of more of it. I believe we never will be able to pass it all along to the chassis. The body will have to carry some of the burden, and I think bodies will need to be made more flexible. If they are made lighter, they necessarily will become more flexible.

In considering this problem we must take all of these features into consideration. We should not attempt to remedy it by requiring any one feature to take care of all the mistakes. Our experience has been mostly with open bodies. We have built open bodies with the idea of taking care of a considerable portion of the twist in the body and have been fairly successful. In the line of enclosed bodies, with longer doors and the roof to take into consideration, they will have to be made flexible to a greater extent than has been true heretofore.

CHAIRMAN NORTHWAY:—We must consider the car as a whole. While we may have to come to having the body and chassis built as a unit, that does not work out as a good manufacturing proposition. Some of the best ideas in the world cannot be put into such shape that they can be successfully manufactured. We must look at car building not only from the point of designing but from the point of meeting the customer's approval and making a profit.

E. A. ROBBINS:—There are two examples of cars in which it appears that the designer has done something to take care of the twist. In the Ford car the frame is suspended from both ends, and the new Overland car is practically suspended from the front and the rear. Regarding deflection of the frame, I have a Ford car with a triangular body brace in front and a coupe body. When starting up a steep hill it buckles just at the front of the body. The hood vibrates up and down fully ½ in.

R. J. S. PIGOTT:—Considering the difficulties in overcoming the inherent strains in the body that are due to the rack or weaving of the chassis, it would appear that perhaps we are not paying sufficient attention to the design of the enclosed body as a box-girder whose joints are sufficiently stiff so that the structure acts as a unit rather than as a number of jointed members. As an instance of treatment of bodies in this manner, a more or less parallel case may be taken from railroad and trolley-car design. A few years ago, Mr. Stillwell devised a body construction for heavy electric interurban cars, which treated the whole body as a box-girder and practically eliminated heavy members such as sills and bolsters. The design of the one man safety-car has accomplished further progress along this line, since the body is used entirely as a chassis and there are practically no longitudinal channel members acting as a frame. The side wall of the car is treated as a deep girder. This is especially true in some of the latest designs, involving the extensive use of automobile materials and methods. It seems easily possible that we can not only average up the amount of distortion over the whole of the body, by making it act as a unit, but also reduce the weight very considerably.

Designers of automobile bodies must face the situation that no chassis, however stiff, can entirely eliminate weaving. Moreover, in a light-weight car, it will probably be extremely undesirable to eliminate entirely the effect of spring yield in the chassis. Therefore, the body designer is faced with two alternatives, either to suspend the body from three points or to design it so that its distortion will be equally divided at all places, such as the joints around the door openings and the cowl.

CHAIRMAN NORTHWAY:—I am acquainted with some men who are working along that line with plywood. Plywood suspension members for airplanes have already been mentioned and this man is attaching the springs directly to the body without any frame.

W. F. EADE:—In designing a car, the air head resistance should be considered in connection with the power required. If the car is of such a shape that the head resistance has been decreased to a minimum then the power required to drive the car can be reduced and a large heavy engine is not needed. The engine power required to overcome air resistance varies as the square of the speed, and one can readily see that a poorly designed car will consume more power merely to overcome air resistance and have less power left for tractive effort.

MR. ROBBINS:—Regarding streamline design for bodies of cars, I think we are not operating them ordinarily at high enough speed so that the form of the body has much to do with the air resistance.

MR. BAILEY:—The wind resistance increases as the square of the relative velocity. At 20 m.p.h. it runs into a lot of power against a 20-mile wind or at 30 m.p.h. against a 10-mile wind.

CRUDE OIL PRODUCTION IN 1920

THE preliminary report of the United States Geological Survey for the year 1920 gives domestic production of crude oil as 443,402,000 bbl. compared with 377,719,000 bbl. in 1919, a gain of 17 per cent. Imports of crude oil into the United States totaled 106,175,000 bbl. in 1920, compared with 52,822,000 bbl. in 1919. These added to the domestic production made the total "income" 549,577,000 bbl. in 1920 against 430,541,000 bbl. in 1919. There were added to the domestic pipeline and tank farm stocks in 1920 a total of 5,823,000 bbl. and to the Mexican crude oil stocks held in the United States by importers 4,523,000 bbl. The exports totaled 8,045,000 bbl. In 1919 there was added to the domestic pipeline and tank farm stocks 6,140,000 bbl. and the exports totaled 5,924,000 bbl.

Deducting the exports and additions to stocks from the total income the indicated total consumption of domestic and imported crude oil in 1920 was 531,186,000 bbl., compared with 418,777,000 bbl. in 1919. The indicated domestic consumption of domestic crude oil in 1920 was 437,579,000 bbl. against 375,559,000 bbl. in 1919.

The domestic pipeline and tank farm stocks held at the end of 1920 totaled 133,690,000 bbl. compared with 127,867,000 bbl. at the close of 1919. Figures on field stocks for 1920 and 1919 are not yet available, except a total of 3,423,276 bbl. covering stocks held east of California at the close of 1920. There was apparently a substantial increase in refinery crude oil stocks at the close of 1920. The latest figures of the Bureau of Mines as of Nov. 30, 1920, placed the quantity at 21,373,945 bbl., compared with 13,143,285 bbl. at the close of 1919.

Figures showing the crude oil record over the last four years are given in the accompanying tables, all quantities being in barrels. The figures are those compiled by the United States Geological Survey and the Bureau of Foreign and Domestic Commerce, except for the refinery stocks which are those of the Bureau of Mines.

INCOME AND OUTGO

Year	Domestic Production	Domestic Consumption	Imports	Exports
1920[1]	443,402,000	437,579,000	106,175,000	8,045,000
1919[1]	377,719,000	375,559,000	52,822,000	5,924,000
1918	355,927,716	380,242,153	37,735,641	4,900,691
1917	335,315,601	351,569,632	30,162,583	4,098,124

STOCKS OF CRUDE OIL

Year	Pipeline Stocks	Refinery Stocks	Field Stocks	Mexican Stocks in United States
1920[1]	133,690,000	21,373,945[2]	3,423,276[3]	7,442,000
1919[1]	127,867,000	13,143,285	[4]	2,919,000
1918	121,727,312	15,749,771	7,547,097	.....
1917	146,041,749	11,638,433	13,705,811	.....

[1]Preliminary figures subject to revision.
[2]As of Nov. 30, 1920.
[3]East of California.
[4]No figures available.

The German Submarine Diesel Engine

By Lieut.-Com. Holbrook C. Gibson,[1] U. S. N.

Motor Boat Meeting Paper *Illustrated with* Photographs

MUCH to the surprise of everyone present at the time of surrender, the German submarines came up to their moorings, maneuvering entirely by using their engines. This performance caused much favorable comment. An inspection was made of the various boats and in the majority of cases it was found that the engines were of Machinenfabrik-Ausburg Nürnburg (M.A.N.) four-cycle reversible type. A few other types were found, such as the Vulcan, Bolhm-Voss, Koerting, Benz, Nürnburg two-cycle and Krupp two-cycle but, comparatively speaking, they were very few in number. In our own submarine service, before the war we had heard

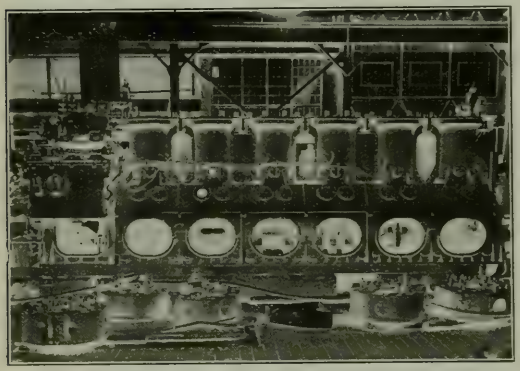


Fig. 1—Side View of a 1200-Hp. Diesel Engine Showing the Steel Construction of the Bedplate and the Housing Which Are Integral Up to the Base of the Cylinder Jacket

much about the Krupp two-cycle engine and naturally supposed that this was the best engine in Germany. However, the Krupp interests were so powerful at that time that they had had their engines adopted for the German submarine service. Out of about 183 submarines which I personally inspected at the time of the surrender, there were only five or six boats that had Krupp engines and they were out of repair. These engines also had one serious objection in that the cylinder-heads and some other parts were made of bronze, which metal became very scarce during the war. As soon as the war was well under way, the German authorities had to listen to the operating personnel and it became necessary to adopt the M.A.N. four-cycle engine, which can be considered as the standard for the German submarine. However, this type of engine was not a war product, but was a practicable proposition as far back as 1912.

During our inspection we found one submarine which was fitted with a pair of M.A.N. four-cycle 800-hp. engines dated 1912. It was about that time that one of our own submarine officers was in Germany. He was shown practically everything in the Ausburg shops except a certain four-cycle engine which was in an enclosure undergoing shop tests. I have reason to believe that this was the engine type which was later adopted for the German submarine service, but it was not until after the war that this four-cycle engine became generally known. Nothing much was heard of it and what one did hear was very vague. Inspections of the German submarine flotilla and various submarine engines and engine plants in Germany revealed that the M.A.N. four-cycle engine predominated. It was being built not only by the Ausburg plant of the M.A.N. company, but at all the other engine plants. The M.A.N. engine is built in the following sizes: 100 hp. at 550 r.p.m.; 300 hp. at 550 r.p.m.; 500 hp. at 500 r.p.m.; 1200 hp. at 450 r.p.m.; 1750 hp. at 380 r.p.m.; and 3000 hp. at 390 r.p.m. The fundamental design of all these engines is the same, but as the size increases certain modifications are necessary. The bedplates are all of cast steel and so are the cylinder jackets. The cylinder-heads and pistons are of the usual material, close-grained cast iron. The crankshafts and connecting-rods are of good quality steel. The M.A.N. engine, with the exception of the 3000-hp. size, is made with six cylinders and an air compressor on the forward end which also carries the fuel pump and a device called the spray air regulator. Everything that is needed to run the engine is located at the forward end, available for the operator.

Regarding the 100-hp. engine, it happened that I went around Kiel harbor in the barge of one of the former German admirals. I noticed that the boat had a quick getaway and high speed. I looked into the engine room and saw that it had a 100-hp. M.A.N. Diesel engine just like the larger ones. This size is a practical proposition; it operated beautifully. This little engine had six cylinders and one three-stage air compressor on the forward end. The engine was air-starting and had a mechanical reversing gear through the clutch.

The 300-hp. type of engine had the same general design characteristics as the 100-hp. size. The pistons of the 100-hp. and the 300-hp. engines are not cooled. The 500-hp. size has six cylinders also and has additional features such as air-starting and reversing and two spray valves in each cylinder-head. In other words, it has a twin spray valve for fuel admission. The pistons are oil cooled in this size.

The unit developing 1200 hp. at 450 r.p.m. is exactly the same as the 500-hp. size; it has oil-cooled pistons and some variations in the type of air compressor. There seems to be no standard practice regarding the use of a three or a four-stage air compressor. In a mine-laying

[1] Submarine Repair Base, League Island Navy Yard, Philadelphia.

cruiser one will find a four-stage air compressor and in another type of boat a three-stage compressor. In the former the compressor is used not only for the engine but for charging the air supply for the ship. That is the only difference in the 1200-hp. type. They are all the same and look as though they had been cut from the same pattern. The 1200-hp. engine can be considered as the German standard, since it was used in a great many vessels; their 800-ton submarine was the standard submarine. A German officer told me that if Germany had concentrated on this 800-ton submarine type, Germany would have won the war. I do not know the total number, but they built 200 or 300 of the 800-ton boats and each was equipped with the 1200-hp. engine.

General Details of Construction

Fig. 1 gives a very good idea of the steel construction of a 1200-hp. engine. The bedplate and the housing are integral up to the base of the cylinder jacket. The bedplates are made in sections to take in two cylinders and they are bolted together with many bolts, resulting in a very substantial construction. The joints can be seen in the illustration. There is a small section on the forward

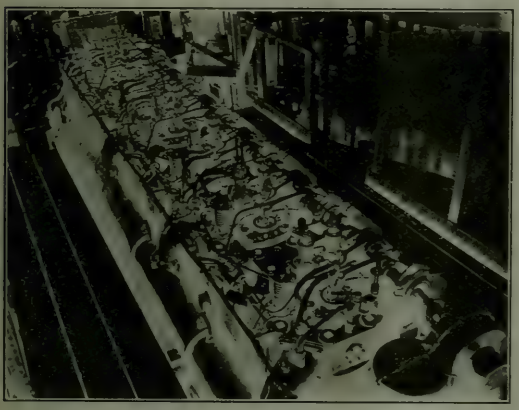


Fig. 2—Looking Down on the 1200-Hp. Engine

end for the air compressor. The cylinder jackets are also bolted to one another and go all the way across on the inside forming a regular girder construction; the result is a very rigid engine but, where it is bolted together, it is free to expand upward. In other words, the bolts that go through the section are not fitted but are loose, the cylinder jackets being able to expand upward.

Fig. 2 shows the engine viewed from above. The principal feature to be noted is the twin spray valve. In my opinion the idea of the twin spray valve was originated on account of the construction of the cylinder-head. If they had cut one big hole in the cylinder-head for the spray valve in addition to the large inlet valve opening, the cylinder-head would have been materially weakened. It looks complicated, but really is not and it works beautifully. The satisfactory operation is simply a matter of accurate workmanship and proper lining up of the valves.

Fig. 3 gives an idea of the mechanism at the forward end. This is the 1750-hp. engine, but it is practically the same except for one additional feature. The fuel pump, air regulator and air compressor are shown. There are three air coolers and below the coolers are the three

Fig. 3—Looking at the Forward End of the 1750-Hp. Engine

separators for the various stages of the air compressor. The wheel shown controls the reversing mechanism which is on the 1200-hp. engine and smaller sizes. It works very easily and one man can handle it without any trouble. This 1750-hp. is the type of engine discovered on the so-called Von Tirpitz super-submarine. These vessels run from 2000 to 2700 tons displacement and were built primarily to operate on the Atlantic Coast of the United States. The engine in the 2000-ton boat is of the 1750-hp. type. As is seen in Fig. 3, it has six cylinders, with air-starting and reversing gear. It has all the earmarks of its predecessors except a few radical departures in design.

Fig. 4 shows the 3000-hp. engine found on the 2700-ton boats which were the largest of the German submarines. It is practically the same as the 1750-hp. engine except that it has 10 cylinders instead of six. The picture of an average man standing alongside gives an idea of the size of this engine. All of the German engines are

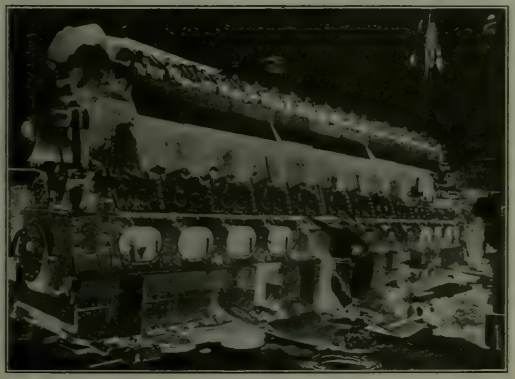


Fig. 4—View of the 3000-Hp. Engine Which Weighs 14,000 Lb.

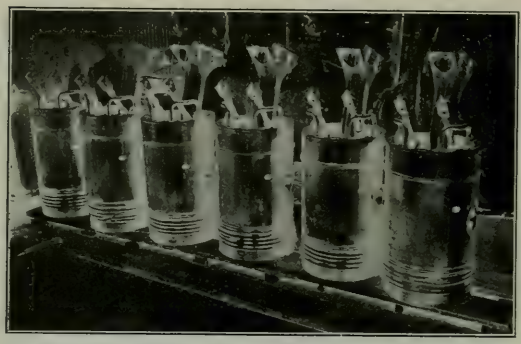


FIG. 5—THE PISTONS OF THE 1750-HP. ENGINE REMOVED

comparatively light for their horsepower. The 1200-hp. engine, complete with exhaust heads, dependent auxiliaries and everything except miscellaneous piping and the oil cooler, weighs 57,000 lb. The 1750-hp. engine, complete with dependent auxiliaries, flywheel, exhaust heads and the like, weighs exactly 97,530 lb. The 3000-hp. engine weighs 72 net tons, or 144,000 lb. One can see in the illustration how the engine is bolted together; all the bolts fit loosely so that the castings are free to expand upwards, but not fore and aft.

Some radical departures are made in the construction of the pistons of the 1750-hp. engine. Fig. 5 shows the six pistons removed. From a casual glance one would think they were exactly the same as those of the 1200-hp. engine. However, when we commenced to clean them up and looked on the inside, we noticed a row of bolts. When these were taken out we discovered that they released the piston head. The pistons are a radical departure in design from their predecessors in other engines. Fig. 6 shows one of them taken apart; the trunk of the piston, with the flange at the top; the piston-head, looking inside; and the cover that goes up inside of the piston to make it a closed cavity so that the oil cannot escape. The piston head is a very fine piece of work. It is a block of semi-steel, machined inside and out. The cavities are for the cooling oil which comes in at the side, works its way around through these grooves and finally into the center and out. Locknuts are provided so that it is impossible for the inside cover-plate to get adrift. A plate goes on over the oil grooves. Some of the groove walls are made thicker than others to provide for the screws which hold the cover-plate on. The bolts that hold the piston head to the flange of the piston are riveted through and they are all locked with lock-pins and locknuts so that the whole is a unit and cannot come adrift.

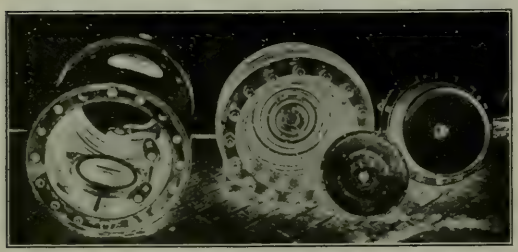


FIG. 6—ONE OF THE DIESEL ENGINE PISTONS TAKEN APART

This design of piston is one of the important departures from former practice. To my mind, it is the most interesting. The cooling-oil pipes are shown which carry the oil in at the periphery and out at the center. The Germans apparently were experimenting more or less with this type of piston for we discovered that the pistons in the engines of the submarine U-140 were slightly different from those of the U-127, although the engine was exactly the same to all appearances. The pistons described were taken from the engine of the U-127 and are apparently of later design.

Another interesting feature about the piston is that on the former engines the pistons were straight from the bottom of the working rings to the bottom of the piston. On this type of piston we found that the skirt was relieved all the way down for a space about 6 in. wide and parallel to the wrist-pin ends. The diameter of the piston is 21 in.

Fig. 7 shows the construction of the connecting-rod and the wrist-pin bearings which is the same throughout all the engines that have cooled pistons. It shows how they provide additional bearing area for the wrist-pin bearings which are subjected to much heat and heavy

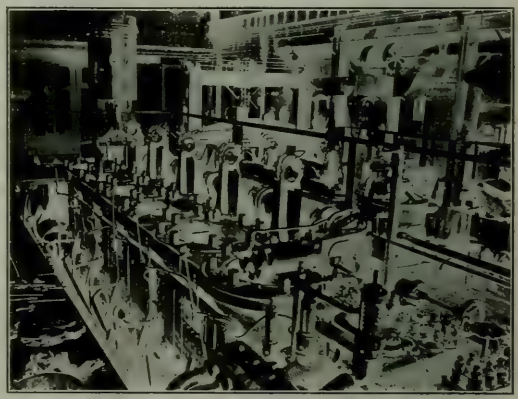


FIG. 7—THE CONSTRUCTION OF THE CONNECTING-ROD AND THE WRIST-PIN BEARINGS WHICH IS THE SAME FOR ALL ENGINES HAVING COOLED PISTONS

pressure. The Germans apparently had no trouble with these bearings for we have had cases where the piston and the cylinder wall have actually scored because of the dirt, and the wrist-pin bearing has not been affected in the slightest degree. A steel forging or casting, I do not know which, goes through the eye of the connecting-rod. It is made in two halves. The upper half of the wrist-pin bearing is shown partly taken out. The lower half has lips or projections to hold the shell in place. The upper half has one small lip and is slipped in last. The wrist-pin bearing is made the extreme width that can be obtained from the inside of the piston; almost double the width of the eye of the connecting-rod is obtained. Naturally, the wrist-pin pressures are very much reduced in this way. The bearing metal, instead of being a bronze bushing, is of comparatively thin babbit metal. They have a fitted distance-piece, measured by micrometers, between the upper half of the bearing and the eye of the connecting-rod. The connecting-rod is drilled out to make it light and when oil is forced to the wrist-pin, this big hole or cavity fills with oil; the inertia of this

oil column tends to pull the oil from the wrist-pin and run that part dry. Instead of putting in a check-valve at the foot of the connecting-rod to prevent this, they have put in a pipe with a screw plate and screwed the pipe into the wrist-pin bearing. The connecting-rod is not filled up with oil and they do not have the difficulty that we sometimes encounter. It is a very simple scheme and there is nothing to go wrong. Another interesting feature in this engine is that the after bearing is of a larger size than the other main bearings of the engine. This bearing is 12.375 in. in diameter; the other bearings are 11.223 in. in diameter. This is done to provide support for the clutch.

Maneuvering Gear

Fig. 8 shows an engine having the same maneuvering gear as the 1200-hp. engine; it has the same handwheel for operating the valve gear. This wheel works through a series of bellcranks and levers and raises the valves clear of the camshaft; the camshaft moves sufficiently to bring another set of cams in line and, to complete the operation, the valve gear is lowered on the new set of cams. On the 1200-hp. engine this was done manually and, while it could be operated readily by the average man, it was a hard task to do this several times per minute in answering the engine room signals. On the 1750-hp. engine this reversing gear can be operated in this way, but it is really all that one very strong man can do; so, in addition to the manually operated gear, a gear is installed which operates by air and also by oil. It is a small box that has four valves in it and by turning a small handwheel in one direction the proper valves are depressed admitting air to a ram. There is an interlocking device on the front of the engine so that when the power-operated maneuvering gear is used the hand gear is thrown out. It is interlocked. When this handwheel is turned, the ram goes over in about 2 sec. and the engine is then ready to operate in the other direction. In case the air pressure fails, there is a small oil-pump provided and the ram can be pumped over with oil pressure. The operating gear shown had not been used in two years and we tried it today to see if it would work, as it is was the only thing on the engine that we did not take apart. We found that it operated very satisfactorily, as if it were put together only yesterday. Another interesting feature on this type of engine, which is simple but, apparently very necessary, is a stop valve on the circulating water supply which is operated by the starting levers of the main engine. It is a sluice valve in the header which supplies water for the working cylinder jackets. It is arranged so that when the operating levers are brought to the stop position the water is cut off from the working cylinders, and it is impossible to supply water to them until the engine is started again. From reading a confidential German instruction pamphlet, I noticed that they lay stress on the fact that cold water must not be put into the engine when it is shut down. The water must be turned off the minute the engine stops. But with this engine, even when using independent electric auxiliaries, it is impossible to damage the engine by pumping cold water into it after the gear has been brought to the stop position. That is a refinement and I suppose it is very necessary. I am also of the opinion that this may have something to do with the air-starting of the engine. In other words, it is not possible to put water on the working cylinders until after the engine has started firing. Consequently, when starting with air, the cylinders are not being cooled with cold water.

Fig. 8—The Maneuvering Gear of the 1750-Hp. Engine Which Is Typical of All the German Submarine Engines

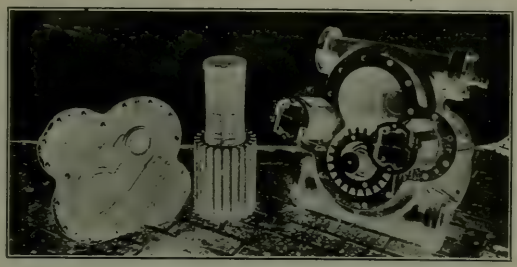


Fig. 9—The Oil Pump Disassembled into Its Various Parts

One other point in the operating gear that does not appear in the older engines is interesting. There are three indicators on the dial of the operating gear, marked *Voraus*, *Tachstellung*, and *Zurick*. The *Voraus* and *Zurick* mean ahead and astern, and *Tachstellung* means diving position. I have been trying to discover a real reason for this third setting, and so far as I can determine, the diving position means the position in which the engine control is placed when the boat dives. It is just the same as the neutral position of the engine, midway between ahead and astern. I think it is one of the refinements that was developed during the war. In case a submarine comes to the surface, the commanding officer is able to maneuver the ship to the best possible advantage. It might also be used in an emergency case, to avoid ramming. If the commanding officer had the controls in the *Tachstellung* position, he would then be

in the best possible maneuvering position for any emergency that might arise.

Fig. 9 shows the oil-pump. One of the great troubles we have had in our own service is to build a good lubricating oil-pump. I do not necessarily mean a pump that never breaks down, but sometimes oil-pumps make too much noise. This pump is the same kind that is used on all the German engines. It is very simple and consists of two gears, one of which is fitted with a cylinder with grooves cut in it. So far as I can make out, the idea is that in an ordinary gear pump a certain amount of oil is trapped between the teeth after the oil has been discharged, creating a tremendous pressure which naturally makes it pound. The pump shown is designed so that, when the teeth are in a certain position after the oil has been delivered and a certain amount of oil has been trapped, the holes come into position and the oil passes by through the groove. This pump is very smooth running and is almost noiseless. I took one apart on a 1200-hp. engine which had been operating for 25,000 miles, but the original toolmarks were still on it and all we did was to put it together again. It is apparently a very satisfactory design of pump and very efficient.

Fig. 10 shows the main engine clutch on a German submarine. It is necessary to have a clutch between the main engines and the electric motors so that when

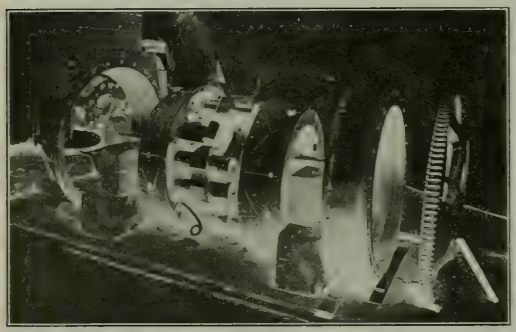


Fig. 10—The Main Clutch of the Diesel Submarine Engine

the boat dives the engines can be disconnected. This clutch is typical of the German design and is very simple. It consists of two truncated cones. The cones slide on a spider, operated by springs. There is a sleeve on the end, with bellcranks to force the truncated cones in and out against the outside casing. The travel is very small, only ½ in. The angle of the cones is 28 deg. The cones are made of cast iron and the outer rings are steel. They are forced in and out by means of a pneumatic piston which is controlled by a small valve. This control enables extremely rapid engagement and withdrawal of the clutch.

Reliability

I have confirmed my opinion that the German submarine engine is extremely reliable. Some thorough tests were made on a 1200-hp. engine without any trouble or breakage. This was an old engine which had been horribly abused. It was overhauled, put in operation, and ran without much trouble. A former German submarine, the U-111, was operating last winter with some of our submarines. It had a green crew and none of them knew anything about the engine. The vessel operated all winter until it came to the League Island Navy Yard for docking and painting preparatory to some speed trials. I talked with the commanding officer, and told him his engine was not adjusted properly, but in spite of this it was running very well and was misleading on account of such satisfactory operation. I persuaded him to allow the gang of men I had used on previous engine tests to tune the engine up for him. It was found that everything possible on the engine was wrong; it was all out of adjustment. The gang cleaned the engine parts, set the valves, ground them in tight and set the parts according to the data we had collected on this 1200-hp. engine on test. The vessel went out burning up its fuel perfectly. She developed over 17 knots, while on the previous trial she could not make 14 knots. This demonstrates that the German submarine engine is reliable and can run even if the personnel are not highly trained. That is a condition we must meet in submarine service.

The submarine Diesel engine is not an ordinary Diesel engine, mainly because the requirements are so exacting. The submarine demands everything of an engine that is difficult to get. The space and the weight are limited; the service and treatment are very severe. The requirements of a submarine Diesel engine might be considered as a quest of the absolute. It must be entirely free from imperfections both in design and workmanship. The Germans spared nothing on the submarine campaign to win the war, and I think the results have shown themselves in the development of the M. A. N. four-cycle engine. Many people who have seen it state that it is complicated. I feel now, since I am more or less familiar with it, that such statements are made by people who have not given careful thought to what the engine is supposed to do. To bring this point out more clearly, I will take for example, a little device on the forward end of the engine which is used to stop it from the conning tower or the bridge of the vessel. We had a similar device on our gasoline boats in the early days. This consisted of a little switch in the conning tower by which the ignition-system circuit on the gasoline engine could be broken in case of emergency. The same idea was proposed for the Diesel engine, but we had a better interior communication signal on the later boats and we did not see any need for it; submarine officers stated that it simply made the engine more complicated. But if we stop and think for a moment, it becomes very apparent that with a larger-sized boat having larger compartments and a big induction valve supplying air to the engine room, when crash diving it is necessary to stop the engines from the bridge to be sure that they are stopped before the main induction valve of the boat is closed. What would happen if the man in the engine room was slow in obeying the signal? Suppose he did not get the signal or was not at his post at the time the signal came through and the induction valve was closed. A vacuum would be produced inside the hull which might kill everybody aboard and cause the loss of the boat. One may not be able to understand at once the reason for everything on a German submarine Diesel engine, but if careful study is made, a very good reason will be found for all of the so-called complications on these engines.

One of the controlling factors in the design of this German engine is the steel castings. I think this is true not only of the German Diesel engine but also of the motorboat engine. The Germans have investigated steel casting to the point where making steel castings is an ordinary, every-day job. I think that has much to do with the success of the German engine for they have

made beautiful steel castings. In this country we have found it difficult to get the steel castings made properly, but after many efforts, we are now making a steel casting for the 1200-hp. engine in the League Island Navy Yard with electric furnaces. We employ a 3-ton electric furnace and have done some experimenting which indicates that the trick is in the coring. The steel is poured into the mold and the minute that the metal has set the mold is broken down to get the casting out. The cores are destroyed so that the casting cannot shrink on a stiff hard core. In some of the difficult castings the core is made so that it will crush and, so far, the results have been satisfactory. It is a job that the steel manufacturers of the United States did not want to attempt. But it was felt in the Submarine Service that it was necessary to learn how to make good steel castings. It must be borne in mind that the German engine is a good type, and the information to the world is three years old. It is not only the United States that has this steel casting information, all the other nations have it. The Germans pour steel like we pour brass and make no fuss over it. We do not want to be satisfied with copying; we must lead.

OILS FOR POWERPLANTS

TAKE a wine glass, dip your finger in water and as you rub it over the edge of the glass notice that the friction is pronounced; now wipe the finger dry and dip it in glycerin and again rub the glass, the friction is about the same. Dip the finger in lubricating oil and rub the glass. You find that the friction is almost imperceptible, which demonstrates that while glycerin has a viscosity far greater than the oil, its lubricating quality is lacking, because the surface tension of either water or glycerin is not strong enough to form a substantial film, even under very light loads, for they are both lacking in capillarity and in molecular attraction. For this reason many very viscous liquids fail to form a good lubricating film.

The static friction of solid surfaces when lubricated with lard and sperm oils proves that the lard oil gives the lowest coefficient and therefore must form the thickest film. Experience teaches that when the superfluous oil has drained away the combined capillary and molecular attraction comes to the aid of the viscosity and increases the tensile strength which tends to prevent rupture. Molecular and capillary attraction are possessed to a greater extent by mineral oils when properly refined, than by either animal or vegetable oils, but mineral oils are deficient in oiliness and will not keep the static friction as low as animal or vegetable oils will.

At 500 r.p.m. or more, under normal loads, and with bath lubrication, lard oil will sustain a film only 0.005 in. thick, whereas a pure mineral oil of the proper viscosity will sustain a film about 0.007 in. thick; which proves that for all ordinary machine bearings running under normal conditions, a mineral oil of the proper viscosity is a better lubricant by two-fifths than one of the best-known fixed oils. This has led to the blending and compounding of mineral oils. Blended oils are a mixture of mineral oil and fixed oils in proportions that will thoroughly neutralize; compounded oils are a mixture of mineral oil with metallic soaps of different kinds for the purpose of increasing the viscosity; experiment alone can demonstrate the value of the mixture.

Solid lubricants such as mica, graphite and soapstone have great carrying power at low speeds, but their value depends on the nature of the surfaces. Graphite gives the best results when used on cast-iron surfaces, which are naturally very porous and hold the graphite, but the frictional loss and wear are great. Solid lubricants mixed with animal fats, greases, vaseline or rosin oil are suitable for low speeds and heavy loads, as they give a low coefficient and do not waste away rapidly by evaporation or run off the bearings. Greases compounded from animal and vegetable fats, or mineral oils emulsified with water soap and alkali enough to neutralize them, are good lubricants for slow-moving bearings with excessive loads, provided the oils do not contain too much water and are not adulterated with foreign substances; the oil should not run down and leave the soap, which is likely to occur in poorly made greases.

Lubricating Oil for Low Speeds and Heavy Loads

In selecting an oil for low speeds and heavy loads, viscosity is the first guide, and next is oiliness. At speeds of 100 ft. per min., with proper application, the oil forms a fairly thick film, and when the load does not exceed 250 lb. per sq. in. the formation of the film and the friction are wholly due to the viscosity; but at heavy loads the bearing surfaces are brought into contact at a point on one side of the bearing and the lubricant should possess oiliness to a greater degree to prevent seizing. In cases of flat surfaces, such as the guide on reciprocating engines, the viscosity is not so important as the oiliness; at loads of 75 lb. per sq. in. a blended lubricant is best.

For motors, generators, turbines and the crankcase type of high-speed engines, best results are had by using a straight mineral oil of the proper viscosity. For motors and generators with bath-ring oiling devices best results are obtained by using a pure mineral oil of a viscosity of from 120 to 198 Saybolt sec. according to the speed and load. Turbines having either forced or circulating lubrication should have a light oil for two reasons: first, because the lighter oils maintain their viscosity better at the relatively high temperatures, and, second, on account of the high speeds. It must also be an oil that will not emulsify and one that will readily separate from water, as there is leakage of steam in most turbines. The viscosity should not be less than 98, nor more than 120 at 100 deg. fahr.

For steam-cylinder lubrication there are four conditions in modern practice that form a guide in selecting a proper oil; namely, steam supersaturated, saturated, dry and superheated. For a supersaturated condition the oil should be heavily blended with pure tallow to give good results; for a saturated condition a light blend of tallow and blown rape will give good results; for dry steam about 6 per cent blown rape gives good results, but for superheated steam one must have a pure steam-refined mineral oil; otherwise the intense heat will burn off the animal and vegetable oil, release the acids they contain and pit the cylinder walls.—C. B. Whitman in *Power*.

EVAPORATION OF CRUDE OIL

THE rate at which crude oil of a given quality and under given temperature conditions will evaporate depends chiefly on the way it is handled. The ordinary method is to pump the oil from the well, force it through a pipe-line gathering system, and then into a tank by overshot connections. In this tank, called a flow tank, any free water is separated by gravity; then the oil is led by another pipe to the lease storage tank. The latter is also filled by overshot connections which permit the oil to fall 8 to 16 ft. and splash into the tank, causing spray. After standing in this tank perhaps 2 to 10 days, the oil is run by the pipe-line company, by pumps and pipe-lines, to the large steel storage-tanks. These have bottom connections and nearly gas-tight roofs. The oil is run from here to large tank farms or directly to the refinery by pipe-lines or tank-cars.

Each of these steps constitutes a different class as regards rate of evaporation. These classes may be divided as follows:

(1) Filling a tank by overshot connections
(2) Filling a tank by bottom connections
(3) Storage in small unprotected tanks on the lease
(4) Storage in small tanks on the lease which have some protection such as shading or an air-tight jacket
(5) Storage in 37,000 or 55,000-bbl. steel tanks which have so-called gas-tight roofs.

Filling the tank by overshot connections is the cause of the most rapid loss. The amount of this loss depends upon several variables, such as the height from which the oil falls, the velocity and size of the stream and the size of the tank as compared with the time required to fill it. Several tests were made which show that the loss in 24 hr. from such conditions ranges from 1 to 2.5 per cent of the original volume in the summer time.

Evaporation during storage on the lease in unprotected tanks shows a high rate. Data obtained from some of the largest independent producing companies in the Mid-Continent field show that the average storage period is five days. In that time oil stored in an unprotected 250-bbl. steel tank will lose from 2.8 to 3.1 per cent by volume; oil stored in a 500-bbl. unprotected steel tank, about 2 per cent; a 1600-bbl. wooden tank, which is protected by a house that acts both as a shade and wind-break, will lose about 1.1 per cent. The above figures are for summer conditions, but tests covering this phase of the subject were run for summer, autumn and winter. Even when the temperature of the oil is low, the loss from evaporation is worthy of consideration. During five days a 250-bbl. tank will, at the average summer temperature of 78 deg. fahr., lose 2.8 per cent by volume, and at the average winter temperature of 38 deg. fahr. 1.7 per cent. Although the temperature has been reduced from an average of 78 deg. fahr. to 38 deg. fahr. and the oil is nearly at the freezing point of water, the loss is still more than one-half of what it would be at the summer temperature. In addition to the tests on housed wooden tanks, comparative tests were made with other types of protected tank. A 500-bbl. steel tank was fitted with a jacket having a 3-in. clearance. Tests of this tank show that approximately two-thirds of the evaporation loss was eliminated by jacketing. A comparison of the cost of the protection with the value of the crude oil saved shows that the jacket would pay for itself in three to four months.

Filling a large tank with bottom connections will cause a rate of evaporation, for a five-day period, which is second only to that from filling a tank with overshot connections, because the oil in the tank is agitated by the inflowing stream and by the ebullition of gas and air, which have been entrapped in the pipe-line. Data were kept on semi-monthly losses in 80 steel tanks having capacities of 37,000 and 55,000 bbl. from which the average evaporation loss was computed. The oil under consideration was that produced near Ranger, Tex., and had a gravity of 40 deg. Baumé. Oil of various ages was tested and the results show that oil stored in such a tank will in the first year lose 3 per cent of its original volume, and in the second year 2.1 per cent. In considering the evaporation losses of crude oil, one must remember that the portion which escapes is gasoline, and moreover the lighter, most valuable part of the gasoline. The value of the fraction is more than three times the value of an equal volume of crude. If a 2-per cent volume loss is shown at any point, this means that 6.5 per cent of the value of the crude has disappeared.

It is possible to eliminate from two-thirds to four-fifths of the evaporation loss by protecting the oil from free contact with air. In a few years crude oil will probably not be exposed to free contact with the air in any case, except when necessary for gaging or sampling.—U. S. Bureau of Mines.

WATER-POWER DEVELOPMENT

COAL alone represents more than one-third of the country's total freight, and much of it has to be carried very long distances to supply the requirements of our widely scattered population. The steam railroads consume more than 160,000,000 tons of coal annually. Under existing conditions of power generation, moreover, the greater our progress in manufacturing, the greater becomes the burden upon our transportation systems in the way of the haulage of fuel. We cannot find a way out of our present difficulties through a retention of the wasteful system of isolated steam-power production with a shifting of dependence from coal to petroleum.

In 1901, when the Federal legislation was enacted under which most of the water-power development of the country has taken place, there was less than 2,000,000 hp. in use. It is estimated that at the beginning of 1920 the development reached 9,823,540 hp., or one-sixth of the maximum potential resources. The Atlantic States south of New England lead the country in water-power development. Among the individual States New York holds first place, with 981,520 hp. developed; California, with 942,000 hp., is second on the list; and Maine, with 780,000 hp., holds the third place among the States in which the streams are utilized for power.

Generally speaking, more than three-fourths of the potential water-power of New England has already been developed; in the remainder of the country east of the Rockies roughly one-third is developed; and in the Far West about one-sixteenth is in use.

In the Pacific States there has been a remarkable development in the construction of long-distance power lines fed with current from a great number of stations. Through the consolidation of utilities and the interconnection of systems there is now in California, from a practical operating point of view, but one vast system, with lines reaching from the Oregon border to Mexico, over a distance of 800 miles, with 75 hydro-electric and 47 steam plants and 7200 miles of high-tension transmission lines. The installed capacity of the system is 785,000 kw. and approximately 600,000 consumers are served. California uses more electric power on farms than all the remainder of the United States. The summer wheat in at least a dozen counties was threshed by electricity. One company supplies power to 60 towns and 500 farms. —*Sea Power.*

METAL FATIGUE UNDER REPEATED STRESSES[1]

THE failure of machine parts under repeated stress has come to be commonly spoken of as due to "fatigue" of the material. The cause of such failure used to be thought to be the "crystallization" of the metal, but the phenomenon is one of a breaking up of crystals rather than of their formation. The development of the internal-combustion engine, the steam turbine, the automobile and the airplane has made this problem of fatigue of materials of increasingly marked moment during recent years. The accompanying table gives some idea of the number of repetitions of stress in the normal life of various structural and machine members.

Part of Structure or Machine	Approximate Number of Repetitions of Stress in the Life of the Structure or Machine
Railroad bridge, chord members	2,000,000
Elevated railroad structure, floor beams	40,000,000
Railroad rail, locomotive wheel loads	500,000
Railroad rail, carwheel loads	15,000,000
Airplane engine crankshaft	18,000,000
Car axles	50,000,000
Automobile engine crankshaft	120,000,000
Line-shafting in shops	360,000,000
Steam engine, piston-rods, connecting-rods and crankshafts	1,000,000,000
Steam turbine shafts, bending stresses	15,000,000,000
Steam-turbine blades	250,000,000,000

The first study of fatigue phenomena on a large scale was made in Germany by Wohler, who published his results in 1870. These results may be summarized as follows:

(1) Repeated application of stress to a structural member will finally cause failure not only when the unit stress is less than the static ultimate strength of the material, but even when it is less than the static elastic limit as ordinarily determined
(2) Within certain limits the range of stress, the difference between maximum and minimum stress, rather than the maximum unit stress, determines the number of cycles before rupture
(3) As the maximum unit stress is increased, the range must be decreased in order not to shorten the life of the member
(4) For the same life in the case of complete reversal of a unit stress, the stress should be only one-half or two-thirds of the maximum stress if the variation is from zero to a maximum

A fatigue failure is characterized by the complete absence of elongation or reduction of area at the break. The fracture is sudden and similar to that ordinarily expected only from brittle materials. A rotating beam will crack at right angles to the length of the beam, which is also at right angles to the direction of stress.

Metals, while being subjected to fatigue, have been observed under the microscope, and it has been found that the crystals of which a metal is composed will allow deformation to occur by movement along certain gliding planes within the crystal. These are called "slip lines," or "slip bands." Careful examination of cross-sections cut at right angles to the surfaces on which the slip lines occur has shown that the slipping causes microscopic ridges and depressions of the surface, in the nature of steps. Vertical illumination of such a surface shows the steps as bright surfaces and the inclined surfaces between the steps as dark lines or bands. As the test of the material in fatigue is continued the slip lines become more numerous and also broaden. Finally some of these develop into a crack which spreads to other crystals and thus causes failure. It has been found that the crystals which first develop slip lines are not necessarily the ones in which final failure occurs.

In general, fatigue failure follows a path through the crystal grains themselves rather than along their boundaries, and this is true even though in going from one crystal to another the plane of failure must change its direction, because of the different orientation of the crystals. It appears, therefore, that the primary cause of fatigue failure is localized deformation. This deformation in any particular crystal is very small in amount and apparently even very accurate and sensitive extensometers cannot detect the deterioration which is going on. Because steel is made up of many minute crystals, the structure is not likely to be homogeneous. Furthermore, there are likely to be many microscopic flaws throughout the material. Somewhere, on account of either non-homogeneity or flaws, there will be high local stresses, and at such places the material will be most likely to deteriorate by the repeated action of fatigue stresses. The presence of internal stresses, due to previous heat-treatment or mechanical treatment, would also tend to weaken the material when fatigue stresses of a similar kind are applied later.

Mechanical Hysteresis Loop

Tests conducted with apparatus of extreme sensitiveness have shown that the action of materials within the ordinary elastic limit is not perfectly elastic. For instance, when a specimen is first loaded in tension, and then the load is reduced to zero, the return path of the stress-deformation curve does not coincide with the original path, but lies slightly lower, the deformation seeming to lag behind the stress, so that when the stress is zero the deformation of the specimen is not yet back at zero. If now the specimen is loaded in compression, and the load reduced to zero, it is found that a loop has been formed by the stress-deformation curve. This loop is called a mechanical hysteresis loop, from analogy with magnetic hysteresis. The area of this loop represents energy which has been absorbed by the specimen but not given back again. In each cycle of stress, therefore, there is a small amount of work done because of the inelastic action of the material. In careful torsion tests Guest and Lea obtained hysteresis loops for mild steel at unit stresses which were very much below what would ordinarily be called the elastic limit. Such results constitute a further explanation of the possibility of failure of a material when stressed within what has heretofore been looked upon as the elastic limit. This so-called elastic limit may be regarded as of value when discussing static stresses, but it seems evident that it is not an elastic limit for reversed stresses, because the hysteresis loops indicate inelastic action. Bairstow has shown that when a cyclical stress sufficiently below the elastic limit is applied to a specimen, no hysteresis loop is formed at first, the amount of damage done during each cycle of stress being apparently too small to be indicated even by a very delicate extensometer. However, after a few thousand repetitions of the stress the cumulative effect of the repetitions is evidently of such a nature as to make measurable the changes which occur in the specimen and a hysteresis loop appears.

In determining the resistance of metals to fatigue, Wohler used machines which subjected the specimens to direct tension and compression, to repeated bending on a stationary beam, to reversed bending on a rotating cantilever beam, to repeated torsion and to reversed torsion. In the direct stress, repeated bending and torsion tests Wohler used machines in which calibrated springs were employed to measure the load applied to the specimen. This general type of machine is quite common. The rotating-beam type, either cantilever or simple beam, has probably been more extensively used than any other machine. Wohler's machines applied the stresses at rates less than 100 per min. so that many weeks of testing were required to stress a specimen

[1]From a paper by H. F. Moore and J. B. Kommers, presented before the American Iron and Steel Insuitute.

as many as 10,000,000 times. In later types of machine attempts have been made to increase the speed of the machines, and speeds up to 2000 r.p.m. have been used successfully. A machine of this kind running 24 hr. per day will give results fairly rapidly.

Various other types of testing machines have been employed by experimenters. In some the stress is produced in the specimen by the acceleration effects of reciprocating masses, in others the pull is applied by an electromagnet, and in still others the reversed bending which is produced occurs in only one plane. Machines for producing reversed bending on a cantilever beam have been used by Arnold and others. These machines stress the materials beyond their yield points so as to produce failure after only a few hundreds or thousands of cycles of stress. In such a test the stress to which a specimen is subjected is not known, and it is therefore difficult to interpret the results. Thus far it has not been shown what relation exists between this short-time test and the test which stresses materials only within their elastic limits. In the ordinary fatigue test the machine is set to produce a certain stress in the specimen, and the test is continued until failure occurs; the number of cycles of stress before failure being recorded by a suitable counter.

Attempts have been made to show that a relation exists between the endurance limit and the elastic limit as determined from a static tensile test. These attempts have not been satisfactory, and this is to be expected, since the endurance limit which was used was itself indefinite. Furthermore, the elastic limit is also an indefinite quantity, and depends to a considerable extent upon the sensitiveness and accuracy of the instruments employed in determining it and upon the accuracy used in plotting the results. It has been shown that a material having a higher elastic limit than another one is not necessarily better in withstanding the destructive effect of repeated stresses for a long time.

There is at present no short-time test which has been proved to be a reliable criterion of fatigue strength. If such a test could be developed it would of course be of the greatest commercial importance.

Tests Being Conducted

In the fall of 1919 there was started at the University of Illinois an investigation of the fatigue of metals under the joint auspices of the National Research Council, the Engineering Foundation and University of Illinois Engineering Experiment Station. This investigation is at present organized and financed to be carried on until the fall of 1921. In planning this investigation it was decided by the advisory committee of the National Research Council that it should be the object of the investigation to make a series of fatigue tests of seven or eight typical steels accompanied by very careful static tests and impact tests, and in connection with these tests various special ones including magnetic tests.

The testing machine chosen for the repeated stress tests is of the rotating-beam type. This gives reversals of a very definitely known bending moment, and there is a considerable portion of the specimen under constant bending moment. The specimen is a straight rod slightly reduced in section over the middle portion of its length.

By past investigators there has been obtained a considerable amount of data on the fatigue failure of metals, but the committee felt that there was need for a comprehensive series of tests on metal whose history was thoroughly known, correlated with very careful static tests of the same material. It is planned for each kind of steel, to run not less than six tests to 100,000,000 repetitions of stress, and to obtain 18 to 24 points on a diagram of fiber stress plotted against numbers of repetitions of stress necessary to cause failure.

INTERNATIONAL CIVIL AVIATION ORGANIZATION

THE wonderful progress made in aeronautics during the war was due partly to the unlimited financial means placed at the disposal of research workers, designers and aircraft manufacturers, but principally to the spirit of mutual cooperation prevailing at that time between the nations entering the two opposite belligerent groups which led to the adoption by all of certain types of machine and the abandonment of others, the establishment of rules and regulations common to all and the cooperative study of the various theoretical and practical problems which to a greater or less extent have some effect on the design, construction and operation of the airplane.

Under the present peace-time conditions we find that the airplane, as it is, is adequate to the requirements of civil aviation. Any attempt to establish civil aviation with a view of serving the needs of one single country only, with the exception perhaps of large countries such as the United States and Russia, cannot be a successful business enterprise because the airplane at the present stage of development cannot compete with the railroad over short distances, especially the present all-wood airplanes. We need cooperation on the part of the various governments in passing laws regulating air navigation, in granting facilities for the establishment of airdromes where needed in utilizing commercial aviation for carrying mail, etc. We need cooperation on the part of research organizations in solving the many problems involved in flight. We need cooperation on the part of aircraft manufacturers for producing efficient types of commercial machine such as they have not yet produced.

All this can be accomplished in a comparatively short time, but if commercial aviation is to be established along international lines and be a good business enterprise, we must not leave it to each nation to work out the problem from within. What is needed is a powerful organization that will approach the problem from an international point of view, establish and operate aerial lines of communication, tying together the most important commercial centers of the world, take the initiative in framing the legislation needed for governing the navigation of the air and be able to outline a program for the aircraft manufacturers of the United States and Europe to work on. This could be the structure, the foundation of commercial aviation that would start operating along international lines and be the pattern on which commercial aviation could be established in each country for serving the particular needs of the various countries in the world and operating in connection with the international air routes.

Three distinct branches of activity are required in such an organization. One branch needs to be concerned with real estate problems such as buying, leasing or otherwise obtaining the necessary grounds at points of arrival and departure of the aerial expresses, construction of hangars, warehouses, workshops, terminal stations, office buildings, subsidiary railroad lines, etc. A second branch will have to deal with the production of airplanes, engines and equipment. The third branch will have to take care of the operation of the aerial lines. Each of these three could be organized as a separate corporation, all three being controlled by the same financial group. Such an arrangement would offer the advantage of possessing the required flexibility for the successful operation of the whole organization.—William Knight in *Aerial Age Weekly*.

Discussion of Papers at the Annual Meeting

THE discussion of the papers presented at the recent Annual Meeting of the Society included written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received, are included in the discussions. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, for the convenience of members who desire to refer to the complete text as originally printed and the illustrations which appeared in connection therewith.

AERONAUTIC PROPELLER DESIGN

BY F. W. CALDWELL

IT is of course impossible to consider propeller design very much in detail in a paper of this nature. It can be said, however, that the airfoil theory, in connection with the inflow theory, has given very good results and proved exceedingly valuable for the aerodynamic design of propellers. Both theories, however, in the present state of knowledge, must be applied with a number of empirical factors.

Propeller-design theories and the subject of aerodynamics are discussed mathematically, as well as the elements governing the best propeller diameter for obtaining the highest thrust. Consideration is given in detail to steel, adjustable-pitch and reversible propellers as well as to those made of laminated construction consisting of sheets of paper fabric impregnated with bakelite as a binder. The mathematical considerations that apply to propellers when reversed in flight, the time and distance required to stop when landing and propeller stresses are enumerated and commented upon.

The tendency of propeller design is discussed and the methods of propeller testing are described. The paper is copiously illustrated. [Printed in this issue of THE JOURNAL]

THE DISCUSSION

PROF. E. P. WARNER:—Mr. Caldwell's paper is of peculiar interest at present because, after having been in a state of constant change and improvement for a number of years, propeller design seems now to be arriving at something like finality. It appears probable, from the work that has been done at Dayton, elsewhere in this country and abroad, that it will be possible within a short time to predict accurately the characteristics of a propeller from nothing more than a knowledge of the sections employed in the making up of that propeller.

As to what is being done abroad, in addition to experiments with the thrust-meter that they are working with, the British are obtaining the pressure distribution on a propeller in flight as well as in the wind-tunnel, to provide data for the application of the new-type propeller-theory to design. The Royal Aircraft Establishment is actually obtaining in flight now the pressure on 105 points of the propeller, and they can build up the thrust and the torque from these pressure plottings. In the matter of strength testing that Mr. Caldwell mentions, the European method is different. The most striking difference to me, after seeing what they are doing in England, is that they attempt to catch the propeller without serious injury, in going against boards or concrete. For that purpose the propeller is surrounded, in both British and German laboratories, with wire fence of an exceptionally springy weave. It has a springy mesh with the idea that, when a part of a blade lets go, it will strike the wire and rebound, be less injured and be easier to examine afterward than if it goes against a concrete wall. They seem to have good success, although they do not test to destruction, as a rule. Usually, they run the propeller up to 25 per cent overload and, if it stands up, do not attempt to break it.

They are working in England with a propeller made up of an aluminum frame having sheet aluminum screwed on both sides as a cover. That was not tried in flight last summer but tests on it were reported to show very good results. It gives a better form than most of the steel propellers that they have had. It is a promising rival to the steel propeller, if wood is finally abandoned on account of its poor resistance to climatic conditions and its poor durability.

THE DESIGN REQUIREMENTS OF COMMERCIAL AVIATION

BY GROVER C. LOENING

AFTER rehearsing instances in the progress of aviation in which an unexpected realization of some radical departure from previous practice led to unwarranted hopes that various aviation problems had been solved completely, the author states six specific false leads or misdirections of aviation development and comments upon them at some length. He then discusses what the influence of war aviation has been.

Passing next to future needs, four specific points of questionable development are enumerated and commented upon, followed by a similar consideration of desirable developments which are grouped likewise under four specific headings, numerous illustrations of present-day airplanes being given including some constructional details of the Junker-type and of metal-covered wings.

In conclusion, the author indicates that it is possible, in a resume of design characteristics and requirements for commercial aviation, to place many developments in their proper category by emphasizing that all-metal construction is a secondary need, a gradual development in itself already resulting in partial metal construction and that, in structural features, what is needed is great simplicity and refinement in the reduction of the number of parts and fittings, whereas in designing and installing the engine, present lines must be followed a little more consistently and patiently to obtain that element of reliability which is more important than any other element in connection with airplane construction. [Printed in the February, 1921, issue of THE JOURNAL]

THE DISCUSSION

R. H. UPSON:—Some evidence on the subject of small single-engined versus large multi-engined airplanes will be interesting. Having made a trip across the English Channel last spring in one of the single-engined planes, and not having the time or opportunity to try the Handley-Page machine in comparison, the best substitute I could get, which I think was really a better means of comparison, was to talk with several people who had tried both and find out the general public sentiment in regard to this subject. I found, without any exception, that the small planes were preferred by those among the general traveling public who had had any opportunity to judge. In the first place, they were faster. That is not necessarily a factor which has to do solely with small machines. They also seemed to be steadier and better liked by people in general.

Regarding the general subject of design, after all, there is no effective substitute for good engineering, which simply means suitability of construction all the way through for the purpose intended.

C. D. HANSCOM:—I was much interested to hear that the Post Office Department found that both engines frequently stopped at once. We have not heard of any instance where that has happened to our planes. The Martin company is trying to keep a service record of each of its planes. If there have been cases where both engines failed, on one of our planes, our records are incomplete.

G. C. LOENING:—I have no information regarding specific instances.

MAJOR L. B. LENT:—I know of no instance where both engines have stopped at once, although that may have occurred. As Mr. Loening has pointed out, the trouble has been due largely to factors outside of the engine itself. The structure of the present engines is entirely satisfactory. We have been using Liberty engines largely. There is still a long way to go, however, in improving fuel systems; most of our failures have occurred from that source. The engines of our twin-engined machines have stopped at various times.

E. R. ARMSTRONG:—We are losing sight of the main thing, which is the carrying of a load a given distance reliably and continuously. It is not a question of two engines or of six engines. I could start a discussion among these engine men as to whether the old single-cylinder Cadillac was as good as the 12-cylinder Packard engine. It is a matter of reliability. I believe that Mr. Loening will agree that if we eliminate things which these statistics show have caused the delay, the twin-engine installation may be just as good as one having four engines. The fact that calls to my attention the suitability of one over the other is the useful load per horsepower. I think that has not been emphasized enough among engineers generally and among people dealing with commercial aeronautics. The usual load is 6 lb. per hp. That is construed as the load of fuel or passengers or whatever else. If, in turn, we interpret this in flight-hours on a basis of 0.5 lb. of fuel per hp.-hr., it means a 12-hr. flight or a 6-hr. flight and a balance of 3 lb. per hp. available for useful load in the form of profit-earning merchandise.

The construction that will give the largest useful load per horsepower is the construction that ought to be worked for, whether it is two, four or six engines. In addition, there is no object in carrying a useful load unless it is carried continuously and reliably. The chief reason for the failure of commercial aeronautics, where it has failed, referring now to 'cross-Channel work particularly and to the mail planes, has been the cost per ton-mile and lack of continuity of flight. We can never hope to carry mail, passengers, express or freight on a commercial basis unless the speed of the airplane is taken into account in reliability. The attention of all automotive engineers should be directed to the design that will produce an airplane that will fly continuously and most economically.

H. J. MARX:—In connection with Mr. Loening's comments on retractable chassis, I wish to add a few notes on some experience I have had recently in adapting such a design to the VE-7 machine for the Navy Department. One of the points I wish to bring out is the fact that I agree with Mr. Loening on a number of matters at present, although I feel that there will be a number of changes in the future that will give a very different and more promising aspect to the entire situation.

First, in designing a retractable chassis, if we keep the same wheel track, we have about 5 ft. between wheel centers. If we retain the same centers in retracting the chassis, we must push it up through the wings or change the angle of the axle from the normal. This causes a number of complications in the actual design of the wings, and also in the matter of streamlining the wings so that the chassis struts are concealed. This means that we lose part of the lift values for that particular portion of the wing section and add slightly more resistance. Another handicap is that the struts must be very strongly constructed, requiring considerable reinforcement in the design and making it rather difficult and expensive to manufacture.

There is no doubt that for a small machine the retractable chassis does not present sufficient advantages to warrant the expensive and complicated installation. If we consider its adaptation to a large-sized machine, we encounter the increased requirements of shock-absorption. If we use the old type of shock-absorber, there is a large mass that we must streamline, which adds considerably more to the resistance. That has been partly overcome by Mr. Martin's design of a shock-absorbing wheel. This is constructed with the entire shock-absorbing device inside of the actual diameter and width of the tire. Adapting this type of wheel to a heavy plane would mean considerable experimental development in that wheel at present, as present design is limited to the lighter type. The retractable chassis also presents serious difficulties

so far as the retracting mechanism is concerned, increasing the weight of the machine above that which the normal chassis requires. It is very difficult to adapt the retractable chassis to a machine that has already been designed and constructed. Those difficulties can be overcome entirely in connection with a new machine, by designing the machine and the chassis at the same time. There are, however, large possibilities for further development of that design beyond what has been attempted so far in the field.

ADRIAN VAN MUFFLING:—Mr. Loening hit the nail on the head when he said that the present-day aviation engine has too many refinements. What we want to do is to develop a strong, rugged six-cylinder engine that is something like a Ford engine, which would be just as reliable and could be adapted on the same principle of standardization as the Ford engine is adapted to the Ford chassis. There is no doubt that the present-day aeronautic engines are built too much like Swiss watches. If anything goes wrong with them it is very difficult to repair them and in most cases one cannot get the needed parts within a reasonable time. Commercial aviation in this country depends upon the development of a standardized, cheap, low-speed and perhaps fairly heavy engine of great reliability.

E. A. SPERRY:—The efficiency of the aeronautic engine ought not to be omitted. Engines on long flights may easily consume many times their own weight in fuel. Efficiency is very important. As Mr. Loening says, we can use a heavier machine if it be more efficient. I do not agree with Mr. Loening's remark that we must plug along with the present engine. A new day must dawn in engines. The aeronautic engine must be not only reliable, as every one agrees, but far more efficient.

MR. LOENING:—I referred to plugging along the present lines in the direction of greater reliability, by reducing the power of the engines of present weight or adding weight to the light engines.

MR. SPERRY:—We must not neglect the very vital point of fuel consumption and efficiency. If we can get far more power out of the fuel, we can carry much more freight or increase the radius of operation very much or both. Moreover, the more efficient machine will not depend upon export or aviation gasoline, but operate upon a fuel that costs about one-fifth of what aviation gasoline costs. Moreover, each gallon of the cheap fuel oil has 25 per cent more thermal units in it. There are many things to be gained by reaching out for improvement and we must not be content with mere "plugging along." Although it may seem to Mr. Loening that the stabilizer got in the way of progress, yet it has made a substantial contribution in a field where the public has not had access to the record of its achievement, which for military reasons has been kept a secret.

SOME EXPERIMENTS ON THICK WINGS WITH FLAPS

BY C. D. HANSCOM

THE subject of thick wings has been taking on a constantly increasing importance in aeronautical discussions for several years. Since the war, with the urgent necessity for instant production removed, aeronautical engineers have been turning to practical experiments. The paper presents the results of tests made for the Glenn L. Martin Co. in the wind-tunnel of the Massachusetts Institute of Technology in an endeavor to obtain more data on the action of wings with flaps. Both front and rear flaps were employed. Ultimately four base sections were adopted and the new wings developed from them.

The first, and most logical, choice was the USA-27. The second base section was the H-1, a wing designed by the author, the data for which have not heretofore been published. A third base section was the D-1, designed by G. M. Denkinger. The fourth master section was a composite curve which resembled no wing in particular. From these master curves six new wings were developed, the details and modifications of these being discussed and their characteristics described by curves and tables of data presented together with considerable detailed comment thereon. [Published in the March, 1921, issue of THE JOURNAL]

THE DISCUSSION

ADRIAN VAN MUFFLING:—Wings have been developed recently in this country that show an L/D ratio of between 26 and 27. It is interesting also to note that the wing-curve is a mathematical curve.

PROF. E. P. WARNER:—For those who are perhaps not able to keep in touch with what has been done on wings, I emphasize the extreme importance and merit of the tests reported by Mr. Hanscom. The 0.00516 lift coefficient obtained is slightly more than 7 per cent higher than any such coefficient that has ever been found before. The highest previous result was obtained in England; this goes far beyond it and it is a much more practical type of wing. Will Mr. Hanscom tell something about the relative merits of the front and rear flaps and whether he thinks the front flap is worthwhile mechanically? Is it not sufficient to use the rear flap alone and leave the front of the wing set in the most efficient position?

C. D. HANSCOM:—Except for very high speeds, very little gain is to be had by changing the position of the leading edge. For a racing machine, or for a machine intended to reach a maximum speed over twice its minimum speed, I think there is value in the front flap; otherwise, not. Professor Warner, having been in charge of the tests that were run, is familiar with these wings.

R. H. UPSON:—Having had considerable experience in airplane trips, especially in those approaching commercial conditions, with the prevailing bumpiness in hot weather, I have wondered whether it would not be feasible to center particular attention on that aspect of the question in the design of the wings themselves. That is, to attempt not only theoretical efficiency but also smooth driving qualities, by the form of the wing, the introduction of spring flaps or something of that nature.

MR. HANSCOM:—I think that would be exceedingly interesting but, aside from the possibilities of the spring flap, I believe much experimenting would be required to determine a wing curve that would give those qualities. I have not gone into that subject and cannot say offhand

whether a variation of section would have a very marked effect on the bumpiness.

A MEMBER: — What relative advantages would the leading-edge or trailing-edge flaps have?

MR. HANSCOM:—They operate in different ranges. The change in the position of the leading edge benefits a wing at high speeds. At all L/D ratios the rear flap is the controlling one.

E. R. ARMSTRONG:—From a practical point of view, am I correct in my understanding that you are seeking a high-speed wing that will give low-speed landing?

MR. HANSCOM:—Yes; and also a very high-lift wing, to carry great weight with small size.

MR. ARMSTRONG:—I imagine that is secondary. In a practical machine such as the Martin bombing airplane, where the speed is 120 m.p.h., what would be the minimum landing speed provided your theoretical deductions were applied to that machine?

MR. HANSCOM:—The testing of these particular wings was finished only yesterday and I have not had time to make examinations as to the properties of the machine. Unquestionably there would be a considerable increase in the maximum speed. These tests have been going on for some time but the last of them have just occurred. Prior to securing the final results we are not doing any development work from the sections.

MR. ARMSTRONG:—What I had particularly in mind is not the maximum speed but the lowest landing speed.

MR. HANSCOM:—If we set a minimum speed, we get a higher maximum speed. It works either way. On the present type of machine the difference, I think, would be between 10 and 20 m.p.h.; I cannot say definitely before investigating further. That includes the benefit derived from partial internal bracing. The wings are thick enough to permit considerable internal bracing.

CHAIRMAN GLENN L. MARTIN:—I think Mr. Armstrong desires to know how much lower the landing speed would be, if the airplane were as it is now with the exception of additional flaps.

MR. HANSCOM:—If a newer wing were substituted the landing speed would be cut down from about 60 to between 40 and 45 m.p.h.

CHAIRMAN MARTIN:—In other words there would be a decrease of from 25 to 33 per cent.

COMMERCIAL AVIATION IN THE EASTERN HEMISPHERE

BY EDWARD P. WARNER

THIS paper is illuminative and affords an opportunity for better comprehension of the remarkable progress and accomplishment made in Europe along the lines of commercial aviation. Reviewing the present European routes now in regular or partial operation, the author stresses the essentialness of the attitude of the press in general being favorable if commercial aviation is to become wholly successful.

The airship appears most practical for long-distance service, to the author, and he mentions the possibility of towns and cities growing up around "air ports." The cost of airship travel is specified, although it is difficult to figure costs and necessary charges because so few data on the depreciation of equipment are available.

Regarding successful operation, much depends upon the efficiency of the ground personnel and organization. It is present practice to send out to aviation pilots by radio telegraph hourly weather warnings which give the height of the clouds, the degree of fog at ground level and details of visibility.

Following a discussion of the matter of Governmental subsidies, the author describes the different kinds of machines and states many of the advantages and disadvantages of single and multi-engined aircraft, his opinion being that multi-engined machines are necessary, especially for extremely large units.

The main subjects considered thus far include the necessity of securing public confidence in the safety and reliability of the service, insurance, governmental assistance, the Air Convention, the matter of passports and visés, customs airdromes, the status of manufacturers, enclosed cabins, the materials of construction, the desirable number of engines, marine aircraft and the possibility of using transferable packing-cases. The illustrations show a few of the types of airplane most commonly used in transport and "taxi" service. [To be printed in an early issue of THE JOURNAL]

THE DISCUSSION

R. H. UPSON:—In the matter of cooperation between manufacturers and operators, Professor Warner mentioned the fact that there seems to be a growing tendency in Europe to keep the operator distinct from the manufacturer. I do not contravert that statement of fact, but I do not object to the possible inference of its being a model to be followed, especially in starting out along new lines. It is of great importance to have just as close cooperation and connection between manufacturing and operating as is possible. I think it will be found that this has been the rule in Europe. Usually, the builders have supervised the operation very closely at the start, and only after it became standardized to the point where the separation mentioned could be effected has this been done. As an example, consider the German airship Bodensee. It was operated not only by the people who constructed it but between two construction stations. This was considered of very great advantage.

It was my experience that airsickness while crossing the English channel is not due to bad air. We had a window open. The trip was as rough as any I have made by boat, but it was completed much more quickly.

PROF. E. P. WARNER:—As to the airsickness I did not base my statement on personal experience. I did not make the Channel crossing in the air but know a number of people who did and some of them were very sick. In the case of one machine on test, the observer was an officer of the Royal Air Force. The pilot came in perfectly cheerful at the end of 2 or 3 hr. but the observer, shut in the little cabin, was very much knocked out. This indicated that the ventilation was poor.

MR. UPSON:—The man who is piloting the machine is responsible for its safety. He has no time to be sick.

PROFESSOR WARNER:—As a matter of fact, I am sure the airsickness was attributable to the fact that the machine was enclosed. There was perhaps something in the design that caused particularly bad ventilation. In regard to the separation of the builder and the operator, I will grant Mr. Upson's point in the case of the Zeppelin company, which controls several other organizations, and in connection with airships in general. The Zeppelin airship works is at Friederichshafen, and about

2 miles from its Berlin terminus; it produces the four-engined airplanes. It certainly is desirable that there should be the closest cooperation between the builder and the operator, but I believe there should be no connection in the case of airplane companies. If we divorce the two, we will throw on the designer the responsibility of meeting competition in the open market. Let us allow the operating man to run his service, and not get the finances of the two mixed up in trying to make the one support the other.

LADISLAS D'ORCY:—Is it not a fact that the report of the British committee on civil aerial transport stated that commercial aviation could not be operated on a profitable basis except through subsidy in one form or another?

PROFESSOR WARNER:—There is a report, issued during the spring of 1920, from a committee made up of ten very distinguished men appointed by the Air Ministry. They say that several important conclusions can be drawn from the evidence given. One is that the transportation of passengers and goods alike is apt to come forward spasmodically; that there does not seem to be any deep-seated confidence on the part of the public in these services. I think that has been overcome. The report of a minority of the committee states that it is not in favor of subsidizing any air company. The majority of the committee advocated a subsidy but this was no adopted.

ADRIAN VAN MUFFLING:—Alluding to lighthouses, just what is their appearance in daylight?

PROFESSOR WARNER:—They have ground-marks all along the route and they are painting the names of the towns all along these routes. Some of the lighthouses are of the form adopted for marine work, with a Fresnel lens directing the rays into the upper quadrants. That has not been altogether satisfactory, and it seemed that better results would be secured by using a searchlight. A single searchlight beam shot into the air can be seen at a distance of 40 miles. I am told that even above a bank of clouds the glow of a searchlight can be seen.

MR. UPSON:—It gives better results to play the searchlight beam around.

PROFESSOR WARNER:—Yes.

E. A. SPERRY:—The vertical high intensity searchlight beams we furnished the Army can be thrown above the fourth layer of cloud. A beam has been seen at a distance of 130 miles when it is waved back and forth. These beams will probably constitute the great beacons for night flying. They are very powerful, the 60-in. giving a light of about *one and one-third billion* candle-power.

PROFESSOR WARNER:—Would that be practicable? Would it be a thing we could afford to run regularly?

MR. SPERRY:—A 60-in. beam has been seen probably farther round the earth's curvature than any light heretofore produced. It requires only 150 amp. at 74 volts, a positive carbon ⅝ in. in diameter and a negative carbon 7/16 in. in diameter. It produces 150,000 cp. raw light without a condenser or reflector.

AERIAL TRANSPORTATION OF THE IMMEDIATE FUTURE

BY RALPH H. UPSON

THE author gives an outline of the fundamentals and divides the subject into a discussion of what aerial transportation facilities we have at present and what should be considered for the future, stating that the inventors must determine how far they can go in providing equipment.

The first question regarding new equipment is, "Will it work?" The next, "Is it safe?" Safety is described as being purely relative, the statement being made that there is no such thing as absolute safety. There is no need to expect danger. We must have both speed and safety and making aerial equipment safe is well worthwhile, no matter at what expense of money and effort.

As to whether commercial aviation can be made to pay, economically and so far as society as a whole is concerned, this is a relative question depending upon the length of haul and the mileage cost.

Charts are shown and methods of obtaining basic costs described, together with formulas and coefficients so obtained. These are worked out for both airplanes and airships. Other charts giving the yearly operating costs of airships, their capital expense and cost curves, and the size of airships required for given cruising radii are shown and explained. The speed and cost data for cargo of varying time value carried over various distances, and the cost of freight transportation, are presented in additional charts. [To be printed in an early issue of THE JOURNAL]

THE DISCUSSION

C. D. HANSCOM:—As I understand it, Mr. Upson has compared the future airship with the present-day steamship, railroad and airplane. Would it not be better to compare the airship with the same period of development of the other means of transportation?

R. H. UPSON:—I have been very liberal, particularly with the airplane. The cost which I have worked out for airplane transportation is less than one-tenth of what is being paid by the United States Aerial Mail. The airship costs are based on airships of present sizes, with a variation only in respect to the possibilities of size. It is wholly a matter of engineering that I am bringing up; not one of invention or of new discoveries.

MR. HANSCOM:—It seemed to me there was the possibility of cutting the cost to one-quarter.

MR. UPSON:—I have assumed an airplane with a gross limit of 15,000 lb., which is rather big for present-day service, and I have taken the most favorable estimates of efficiency for that purpose.

MR. HANSCOM:—That would approximate the conditions they have with the aerial mail.

MR. UPSON:—No; the aerial mail is costing over 10 times as much.

PROF. E. P. WARNER:—It is very desirable and necessary that night services be put into effect. I would like to know how Mr. Upson reconciles his advocacy of the single-engined plane with the desire for night flying.

MR. UPSON:—I was merely citing some interesting personal observations of particular planes that have come within my field of experience. I hold no brief, necessarily, for the single-engined machine; it is all a matter of suitability and design. If we are going over a country where it is of the utmost importance to have

reliability and it cannot be had in any other way, we can multiply the number of power units.

MAJOR L. B. LENT:—The Aerial Mail Service has been running between New York City and San Francisco since September, 1920, with several stations in between, and other branch lines, between Chicago and St. Louis and between Chicago and Minneapolis, have been running. We have been keeping accurate account of the cost of this service. While the Army and the Navy have been very good to us in supplying needed equipment, the cost of all the equipment is charged against the Aerial Mail Service and the Post Office Department figures, which are available to everyone, are accurate and can be relied upon. The cost, as we figure it because of our variable loads, runs about 70 cents per mile the year around. With proper equipment and an organization which might be developed that would be unhampered by law and regulations, I think that cost could be cut in half.

Our experience has taught us that the only excuse at present for a multi-engined plane is to get that plane from one major stop to another without a forced landing. We have forced landings from two causes, the weather and engine trouble. I think we should change from one engine to three. If one engine of a two-engined plane quits, we have lost 50 per cent of the power. If the plane is fully loaded, we have not enough power to drive the machine on to a major station where it can be landed properly and taken care of. Right there is an item of the cost of our Aerial Mail Service that is enormous, in comparison with actual operation cost. This maintenance and repair cost is much higher, including bringing in the machines from forced landings, when it is impossible for them to get out or they are damaged in getting them back to a repair station, replacing parts and putting them in flying condition. The other large maintenance cost has already been brought out. The planes we are using today are revised war-planes. The trouble we have in keeping these planes in flying condition is unbelievable, unless one encounters it from day to day. We have to deal with it because we are flying in all kinds of weather. Our performance is from coast to coast; it has not been as high as it might have been.

In speaking of the types of carrying plane, I think it is better, from the commercial standpoint, to divide the load between a number of single-engined planes. If the total load is carried in one plane and it has a forced landing, the whole service is delayed; while, if the load is distributed among four planes and two get through, at least one-half of the service has been performed. Where aerial trade is predicated on delivery of goods within a specified time, the customer demands that those goods be delivered.

Returning to the question of maintenance, the Society of Automotive Engineers has a work to do which I think is most important and that is practically to clean up the present type of plane so that it will be reliable. In a small way the Post Office Department is trying to do this. Usually engine failure is not due to faulty design but to the auxiliaries of the plant such as shaky radiator fastenings, small gas leaks and ignition apparatus out of commission. When coming in out of the snow, a rudder might be ripped off and so on. There is no more excuse for an unreliable gas system in an airplane than in an automobile. That part of the airplane must be made reliable. When those little things that are sources of constant annoyance shall have been cleaned up, we will have an airplane that has a fair amount of reliability.

The Aerial Mail Service has been running about 2½ years. If we could proceed as we would like to proceed, we could accomplish many things that we cannot accomplish now. But the record of the Aerial Mail Service will show that commercial aviation is a real, practical problem. The cost is not excessive and it can be reduced readily. I am informed that there is a large volume of business which can be had and would pay rather good dividends on the cost of operation. It may not come in the very near future, principally because the landing fields and routes have not been laid out. Places to land, places to take care of the machines and a complete organization equipped with repair shops and all paraphernalia on the ground are necessary to keep a line in constant operation. There is a vast difference between fair-weather flying when it appears desirable and running a commercial aerial line on a schedule. Ability to fly in any weather will come, I think, very shortly. The one thing that hampers us now in flying is having to wait for good weather. The pilots will not go above the clouds and fly because they do not have the necessary navigating instruments to find their way. Wireless apparatus is available which will enable a pilot to fly above the clouds and come down and find his field. He actually can talk to the stations and find out where the landing field is. We have done that. In landing at night, the incoming pilot can notify the landing field and flyers can be sent out to meet him, even long after dark. Until we can fly above the clouds and disregard landmarks we will be handicapped in commercial work. The pilot flying over the Allegheny Mountains flies under the clouds, practically brushing the treetops all the way from New York City to Cleveland. That may be all right for carrying mail, but passengers cannot be carried in that way. The next step in real development is to secure more reliable planes by paying attention to the auxiliaries. I think we are not very far from such accomplishment.

COMPRESSION RATIO AND THERMAL EFFICIENCY OF AIRPLANE ENGINES

BY S. W. SPARROW

APPRECIATING the fundamental relation of the compression ratio to the thermal efficiency, the National Advisory Committee for Aeronautics sponsored a comprehensive investigation of this subject at the Bureau of Standards. Every effort was made to measure the engine performance so completely as to make possible an analysis that would not only explain the results of this particular series of tests but form a sound basis for predicting the effect of changes in the compression ratio on the thermal efficiency of any engine. The experimental work is as yet incomplete and only some of the more salient results are presented in this paper.

An eight-cylinder airplane engine was used, having pistons allowing compression ratios of 5.3, 6.3, 7.3 and 8.3. The differences in compression ratio were effected by crowning the piston-heads different amounts. The tests were made in the altitude-chamber to secure typ-

ical altitude conditions of air temperature and pressure, and those presented in this paper were made under full load at an engine speed of 1600 r.p.m. The resultant data are exhibited in charts and these are analyzed. [Printed in the March, 1921, issue of THE JOURNAL]

THE DISCUSSION

O. C. RHODE:—What kind of fuel was used in the Bureau of Standards' engine tests?

S. W. SPARROW:—Aviation gasoline was used in all of the tests.

GEORGE W. LEWIS:—The National Advisory Committee for Aeronautics is, of course, very much interested in the development of commercial or civil aviation. The whole future of the aeronautic industry is dependent largely upon the proper development and encouragement given to it at present. The National Advisory Committee for Aeronautics has laid out a tentative program for a civil airplane contest. The rules and regulations for the contest are strongly recommended by Professor Warner, who has spent two weeks studying the rules, regulations and actual operation of the British commercial airplane competitions.

One of the most important, if not the most important, development in connection with civil aviation is the establishment of landing fields for airplanes. Captain Hartney recently presented a report in Washington giving outlines of a program of the Army Air Service for establishing an airway between Washington and Dayton, Ohio. The airway will provide not only for airdromes but emergency landing fields and markers so that the pilot can at any time determine his exact location. The airway will be laid out so that it will be possible for a pilot who has never gone over the course to make the trip without the usual delays. The Army Air Service also expects to provide means for flying over this course at night. The establishment of this particular airway will make it possible for the Army to use a number of excess steel hangars that are now in stock, as they can be erected at the different landing fields along the airway.

HIGHWAY-ROAD CONSTRUCTION

BY W. E. WILLIAMS

STATING that asphalt, brick and concrete-slab road-surfaces are the only pavements that have given satisfaction for automobile traffic, the author believes further that thus far the concrete-slab surface is the only one worthy of consideration for such traffic. He discusses the merits and demerits of these surfaces and includes an enumeration of the factors that combine to produce a thoroughly satisfactory road surface.

Passing to a detailed review of the bearing value of soils and the correction of road failures, the author presents data and illustrations in substantiation of his statements and follows this with a consideration of the reinforcing of a concrete road slab with steel.

Regarding the ultimate highway, it is stated that a concrete-slab road, about 8 in. thick and of uniform depth across the road, perhaps with an increased thickness of integral supporting curb-block on the edges in some locations, is the type of road that should be built in this country, and reasons in support of this are given. The subject of impact is discussed and its meaning explained. [Printed in the February, 1921, issue of THE JOURNAL]

VARIABLE FACTORS IN HIGHWAY DESIGN

BY H. E. BREED

IF prospective traffic, soil conditions, drainage, surfacing, maintenance and political influence were definitely known quantities instead of being algebraic unknowns, the problem of highway design would be simple; but all are variable and we can measure them at present only by empirical generalizations. Neither ignorance on the engineer's part nor carelessness or fraud in construction is the cause of many of the highway failures; the variable factors involved simply defy the best opinion and practice obtainable.

The factors governing the most desirable type of pavement, prospective traffic and cooperative methods between highway and automotive engineers are then considered, followed by comments on the subjects of road foundation, drainage, surfacing and maintenance. The subject of political influence as it affects highway departments is discussed at some length, the evils of such influence when it is detrimental are emphasized and remedies for them are suggested. [Printed in the March, 1921, issue of THE JOURNAL]

AUTOMOBILE OBLIGATIONS TOWARD HIGHWAY DEVELOPMENT

BY H. W. ALDEN

THE author brings to attention very emphatically the responsibility of the automotive industry for some things besides the actual building and selling of motor cars.

The progress of civilization can be measured very largely by advances in means of communication. The transfer of messages by wire and wireless has made wonderful advances of a fundamental nature in recent years, but the transportation of commodities from place to place has not made such strides. The automotive industry has been concerned mostly with the actual development and production of the motor car and, as an industry, has stopped there without developing those allied activities which are vital to the long-time success of the business. The railroads afford a good example to follow in principle. Their roadbeds and the equipment operating thereon have been improved and developed hand-in-hand by the same general guiding influ-

ences and their wonderful advance in both is due fundamentally to this unified control of these two elements. A different condition exists to-day regarding highway transport. We have far better highways than formerly, but the author believes that the ratio between the demand on the highways and their ability to meet that demand has gone down rather than remained constant.

After expressing his sympathy with the difficulties confronting the highway engineer, the author rehearses the factors governing merchandise transportation and outlines means of betterment that should be promulgated by automotive engineers, with special reference to the construction and maintenance of highways for motor-vehicle use. [Printed in the February, 1921, issue of THE JOURNAL]

INVESTIGATIONS OF ROAD SUBGRADES

BY A. T. GOLDBECK

THE problem of the subgrade is evidently that of finding what causes certain kinds of subgrade material to be soft and of very low bearing value and, having ascertained this, to determine what means must be employed to either remedy the condition of the subgrade or fit the design of the road surface to the subgrade. The author considers the mechanics of the problem and some of the various factors involved in producing an unstable condition in the subgrade.

The paper is illustrated with charts plotted from data obtained relative to the bearing power of soils, intensity and distribution of pressures, various forms of road construction in connection with the principles underlying the drainage of subgrades and impact tests, The road tests made at Camp Humphreys are described. Soft subgrades are considered at length; the drainage problem in general is discussed and results of laboratory investigations of subgrades presented. Bearing value tests of soils and drainage investigations are next considered specifically. [Printed in the April, 1921, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN H. W. ALDEN:—I doubt if there has been a time in the history of the automotive industry when it was as necessary as now for it to get out of its so-called legitimate line of work and pay attention to some other things. The matter of how highways shall be built must be left largely to the highway engineer who has been trained for that work, but that does not relieve the automotive industry of its responsibility to turn to and help. While I have been rather severe in my criticism of what the automotive industry has done in the past, I think it is well borne out by the facts and that we have not done our share by any manner of means. The same thing is true about the handling of merchandise. We build trucks and sell them to dealers to operate with no particular attention given to their correct and logical use, except in a very few cases, as at Cincinnati and Cleveland, particularly in connection with other transportation facilities.

W. E. WILLIAMS:—The term "hammer-blow," in place of "impact," will be better understood by the layman as a road-destroying factor. "Hammer-blow" was the term in common use with railroad track men years ago. As it relates to brick pavements, the hammer-blow of the iron-tired vehicles and the shoes of horses soon breaks off the corners of the bricks of the best laid brick pavement, until it becomes a continuous series of offsets producing vibration on the vehicle wheel treads that injures both the road and the vehicle. That the drainage should be good is so axiomatic that I need not dwell upon it. If it were possible to have a dry subbase, a thin hard surface would be sufficient.

CHAIRMAN ALDEN:—Mr. Williams has, to my mind, put his finger on the solution of the highway difficulty, but I do not agree with him that it is in limiting, within so-called reasonable ranges, the weights of vehicles. I question very much whether the present-day trucks are heavier than the well sub-soiled road is perfectly capable of standing. The Federal Highway Council has done much work along this line and has started to accomplish some very remarkable results in the coordination of various organizations working toward the end of improving the subgrade. They are finding out some very remarkable things. As Mr. Williams says, moisture in the subgrade is the enemy of the road. It is beginning to be apparent, however, that it is perfectly possible with proper knowledge and precaution of the soil in which the road is to be placed, to get vastly increased supporting power of the subgrade from what had been current practice today. In nearly every case where a failure occurs, the bearing power of the subgrade has been criminally low, much lower than necessary under the conditions confronted. This is not meant as a criticism of the highway engineer, because he also has had other problems to meet.

S. W. WILLIAMS:—A number of nationally known organizations, such as the American Automobile Association, the National Automobile Chamber of Commerce, the Federal Highway Council, are earnestly and conscientiously attempting to solve the difficulties obstructing highway development. It is somewhat of an undertaking and is discouraging, but we are encouraged when an organization such as the Society of Automotive Engineers cooperates with us.

I have listened with greatest interest to the papers presented and discussed here today and I am much impressed. I am in entire sympathy with Mr. Williams in that we need roads, that we need more roads and that we need them just as fast as it is possible to build them, but I doubt very much if we want to begin to fit this new type of transportation to the road or highway rather than the highway to the transportation. A prominent highway engineer said in my presence recently that no highway engineer in the United States today knows how to develop a highway that will serve the transportation needs of the country 5 to 10 years hence. I believe that an analogous condition prevails in this Society. I doubt very much if automotive engineers have made up their minds that they know the type of vehicle that will serve the needs of this country. We fail to realize that the highways of this country have an earning capacity, and that earning capacity will be increased with the economic service rendered. Therefore, the real controlling factor in both the highway and the vehicle will be the transportation needs of the communities. We are not in a position to say today what we shall build, nor should we encourage the public to believe that we should curtail beyond a certain reasonable limit the capacity or the type of truck that will be or should be used on the highway.

Mr. Goldbeck covered his subject in such a thorough manner that I can add only that the word drainage has

come into such common use in this country that I am afraid it has been misused. I am satisfied that engineers are awakening to the fact that the real necessity is not to take the moisture out of a road, but to keep it out and away from the road. If we do that, we will have dry surfaces, in a short time dry subgrades, and in a little while longer we will not hear any more talk about the size of the truck that will use the road, because the dry road will stand the weight. I am satisfied that so far as is possible in reason, without handicapping the needs of the communities, we should attempt to protect the roads that we have already constructed until we are able to build the roads to meet a greater need.

Mr. Breed referred to the political situation. Unfortunately, the position of the State highway engineer in this country has been made a political football. We must obviate that, but we cannot do this until the public awakens to the seriousness that surrounds such a custom. I am not criticising any other State more than I am the State I come from. Only a short time ago a change in administration took place there. Immediately there was a change in the State highway officials. That change was brought about by a change of governors. Politics was allowed to come into the situation so completely that the new administration refused to confirm the appointee of the other party. I condemn that, notwithstanding that I belong to the political faith that was guilty of the act.

In regard to national legislation, unfortunately the views in Washington and of those throughout the country differ; some are striving for one thing and some for another. It is rather difficult to say at this time what the outcome will be. The different agencies that are represented and that have been working for months are conscientiously trying to get together to solve the problem to the best interest of all, and we are hoping to establish at this or the next session of Congress a separate responsibility in an administrative organization by which the highway problems will be handled. We believe, in view of the large expenditure of money involved, the millions already available and the many more millions to come, that the time has arrived when the highway-building responsibility of this country should be centered in a board responsible to no other department of the Government; in others words an independent board.

Considerable reference has been made in newspapers and in publicity matter to the fact that we have today between $700,000,000 and $800,000,000 available. It is creating some amazement among the people that we have such a large amount of money. It will be unfortunate if that opinion becomes general, because that sum is simply an accumulation over a period of practically 3 years. When the highway needs of this country are considered, it is a small sum comparatively. The day is coming when we must spend that much, if not more, to meet the transportation needs.

A MEMBER:—In 1872 I did some of the first work in New York City with asphalt pavement. In 1866 Carroll Beckwith investigated road building in France and made a full report to the United States Government. Attention was called to the good results in the use of asphalt. Some years ago Mr. Williams, of Washington, stated that the railroads were not helping road-bui'ding. I took exception to that. I take exception also to the statement that automotive engineers have not done an immense amount of work for road improvement.

In 1908 I was appointed consulting engineer of the Quaker City Motor Club. In that year we had the greatest race that was ever known in the United States, in Fairmount Park. We had a large number of visitors. Marvelous improvements have been made since that date, but I wish to emphasize the fact that I have had during my career very splendid assistance from the people interested in automobiles and in motorization. One of my family, James Boardman, was largely instrumental in establishing the railroads of the State of New York. I wish to be instrumental in helping to establish the great motor roads. Motorization is absolutely the requirement of the day. When the late President Roosevelt asked what the best thing was for the uplift of the farmer, a number of points were mentioned but I replied "good roads." We must have good roads and we must have roads that can carry this motorized transportation system. Just after the close of the war, Mr. Morse, who had had charge of the railroads for the Government, said that the railroads were not adequate by any manner of means for the transportation of today. He stated that there are a number of railroads that cannot pay for their own maintenance. He suggested that the rails be removed and that these old railroads should be converted into roads.

I disagree with Mr. Williams' statements. Several years ago I stated at the Philadelphia Engineers' Club that there were at least 20 different types of road that could be made absolutely serviceable. There is nothing better than granite for certain places. While I confess my preference for asphalt, there are at least 20 different classes of road that can be and are being built today. I think I am about the oldest man engaged in highway construction. I appreciate what has been done by the engineers connected with the production of automobiles and engines in the way of road construction. I think they are doing magnificent work. We all gratefully acknowledge the aid that we have had from the people in the automotive industry.

CHAIRMAN ALDEN:—The automotive industry appreciates the courtesy of the foregoing compliments, but I think it has not done anything like what it should do and what I feel very sure will be done in the next few years. There are indications that the railroads, the waterways and the highways are being brought together now in a way that is most gratifying. This meeting has been devoted largely to the road end of the highway question. We shall probably have at the Summer Meeting a session devoted entirely to the question of transportation, so far as the getting together of the railroads, the motor-car companies and the highways engineers is concerned, for consideration of the municipal and terminal transportation of goods and merchandise.

DAVID S. LUDLUM:—Will Mr. Goldbeck say how many different makes of chassis were tested in Washington?

A. T. GOLDBECK:—According to my recollection, there were from six to eight.

MR. LUDLUM:—How far do you expect to go before you recommend one design of chassis?

MR. GOLDBECK:—We do not expect to go that far. We are simply trying to find out how much pressure and how much impact are exerted on the roads, due to the different weights of vehicles. We feel that the thing to work for is the rational design of pavements. If that is so, one of the fundamental things to discover is how much load is being exerted on the pavement. Therefore, we are trying to use as many of the heavy trucks as we can, and I think that we have used a sufficient number.

MR. LUDLUM:—Have you tried a truck with a short wheelbase? One company has advertised broadcast its

deductions from what you have said. I am curious to know whether you have tested out a short wheelbase and the drive through the rear springs without torsion rod?

MR. GOLDBECK:—I think we have not.

MR. LUDLUM:—That was offered to you last summer. I am wondering how far your department is going in the public press before you have tested out everything to find out how much is involved in the way of investment in motor trucks in this country.

MR. GOLDBECK:—It is almost necessary for us to get out progress reports. I would prefer to finish the investigation and come to definite conclusions before issuing any report. In fact, we have been trying to go rather slowly; we could have published some additional information some time ago, but we have been holding it up. However, we cannot hold it up very long. We are entirely willing to test any make of truck; in fact, if it is thought that any particular make will have any influence on the design of roads, we want to test that make.

CHAIRMAN ALDEN:—Perhaps the Bureau of Public Roads would send to the National Automobile Chamber of Commerce copies of each of its reports. Then those concerned could govern themselves accordingly.

MR. LUDLUM:—That would be satisfactory.

R. A. MEEKER:—Some things have been left unsaid. It is true that drainage is an essential feature in the construction of all roads; however, sometimes an engineer is condemned for faulty drainage when it is not his fault. The American public has an idea that it is only necessary for us to build a road and we can then go away and forget it. It is just as essential that a road should be maintained and carefully watched as that any motor vehicle should be carefully maintained. Where would the motor truck be if it were not maintained properly? Along the same line of reasoning, very many people condemn roads. The foundation of a concrete road should be resilient to a certain extent. There is no resiliency in a slab of concrete. It is "as hard as a rock." It will break under impact. It seems rather strange that in designing concrete roads we have neglected all that we learned in designing concrete sidewalks. No man would think of laying a concrete-slab sidewalk without carefully excavating the earth underneath and filling in with some pervious material such as cinders or sand, thus making a cushion for the slab, but who does that with concrete roads? The roads fail and then that type of road is condemned.

Some years ago one of our county engineers was taking up an old stone road. I suggested that he take everything out of the road, bring the subgrade to an elevation about 3 in. above the finish of the subgrade and then plow the whole thing from side to side. He doubted this. However, he tried it. Now there is a concrete road 3½ miles long that has no cracks in it except in two or three places, and those are due to neglect of the drainage. The underdrains were put in and the road was properly drained, but they were broken and nobody repaired them. When the underdrains were examined they were found to be mashed in.

After a road is built, constant and minute attention must be given to it just as in the case of a motor truck. If that is done, good results will be obtained and there will not be so much complaint that roads are not strong enough to carry the loads. If the road is to be taken care of and the drainage properly looked after, we need to follow the old plan of the railroads of having section gangs and track walkers. Place the gangs in the spring and in the fall, have them go over the road and fix up what is necessary. Then assign from 3 to 5 miles of road to a man and keep that man on it as long as the road is in good condition. If his section of the road goes bad, get another man.

A MEMBER:—Mr. Williams states that experience has proved that an asphalt surface will not stand up under heavy truck traffic. The service records of asphalt pavements throughout the country, on both rigid and non-rigid bases, are contrary to this assertion. Like any other pavement, the serviceability of asphaltic types depends largely upon the support furnished the pavement from below. Mr. Williams apparently pins his faith to the beam strength of rigid pavements and states that asphalt surfaces aid a concrete base but slightly in sustaining beam loads. In this connection it is rather significant that many miles of rigid pavements which have failed under heavy motor-truck traffic, are now being successfully salvaged as foundations by laying an asphalt wearing course upon them. This, I believe, is the present practice in Maryland. As a matter of fact, asphalt paving mixtures not only possess considerable beam strength but greatly increase the beam strength of the rigid types when subjected to impact, which is recognized as the most destructive traffic agency on a pavement. This fact has been demonstrated by recently conducted tests the results of which were published in the *Engineering News-Record* for Dec. 30, 1920.

I believe that if as much attention were paid to the suitable preparation of subgrades as to the increase in the massiveness and strength of pavement design, our paving problems would be solved much more quickly and economically. It is not believed that rigidity in the design of pavements is any more logical than in the design of motor trucks. The motor truck itself, as well as the load it carries, is logically protected from the shocks of traffic by rubber tires and springs. No one would for a moment believe it advisable to construct a perfectly rigid truck and increase its massiveness of design to withstand the destructive agencies of traffic. Why then should such practice be recommended in the construction of highways?

D. C. FENNER:—Mr. Williams' paper states that on the heavy-capacity trucks the wheel load runs from 4 to 8 tons, which is supported upon a tire area of 48 sq. in. Partly to satisfy my own curiosity in that respect, I took a 7½-ton truck equipped with 14-in. rear tires, placed the truck on a concrete slab and reduced the pressure to 105 lb. per sq. in.

H. W. SLAUSON:—One of the interesting features of Mr. Goldbeck's paper is his reference to the effect of differences in inflation pressures of pneumatic tires, in regard to impact pressures. I understood him to say that there was no difference whether the tires were pumped to 110 or 160 lb. per sq. in. My interpretation of the effect of impact has been the absorption by the tire of the hammer-blow struck by the loaded wheel when it travels through the air and strikes the road. We all think that an under-inflated pneumatic tire rides more easily. If that is the case, why is the impact the same? Are we wrong in thinking that an under-inflated tire rides more easily, or is there a difference that is not observed with the truck?

MR. GOLDBECK:—An under-inflated tire does ride more easily and, as a matter of fact, the tests do show a somewhat higher impact for the more highly inflated tires. In regard to the theory of impact and what we mean when we speak of impact, we know that there is an old law in physics which says that a force is equal to the

mass times the acceleration. This means that if we have a weight at rest whose mass is M, and we act upon that weight with a force F, thereby increasing the velocity of that weight from zero up to a certain maximum velocity in a given time, we will have accelerated or changed the velocity and that is this quantity A. We can see readily that the shorter the time required to change the velocity from zero up to a certain maximum, the higher will be the quantity A, because the acceleration is equal to the time-rate of change of velocity. The higher the acceleration is, the mass remaining constant, the greater the force exerted on the road surface will be.

What do we have when a truck tire strikes the road surface? We will say that the tire is just about to fall from one level to a lower level. The tire strikes the road surface and begins to flatten out. At this instant there must be a reaction created between the road and the tire. The flatter it becomes the greater that force will be. In other words, we have a variable force acting between the tire and the road surface, depending upon the extent to which the tire is flattened out. Suppose one tire flattens out much more than another, in bringing that load to rest. This generally means that there is a longer time required to bring that load to rest; a longer time means smaller acceleration, because acceleration is equal to the velocity divided by the time. The longer the time is the smaller this quantity A will be, and the smaller the acceleration; so, the theory shown that the greater the deflection of the tire, the longer will be the time required to bring the unsprung weight to rest and the lower the acceleration, and, from this formula, the lower will be the force exerted on the road surface.

That is not the only force exerted on the road surface in the case of a truck wheel because, when a truck wheel strikes the road surface, it is influenced not only by the force of gravity but by the compression in the spring; so, we must add to that the quantity C, which is the amount of compression existing in the spring at the time the truck tire comes to rest. This whole question of impact is merely one of the time required to bring the weights to rest in a vertical direction.

CHAIRMAN ALDEN:—The curves did show a difference between 110 and 160 lb. per sq. in. It is not negligible. This question of the time element and the yield is a very important one.

W. E. WILLIAMS:—From some of the statements made, this audience appears not to be closely in touch with the men who are building and supervising roads. Road engineers would like to build the very best roads in the first instance and to be able to say that they are permanent highways, but the cost will not permit that. When we began to build railroads in this country, one railroad built on this basis was an example of a splendidly constructed road, but it nearly bankrupted the country.

If one goes into the history of the financing of our railroads generally, one will find that what I have said about cheaper roads and large mileage is true. Legislation is bound to be passed to do exactly what I have outlined about limiting the heavier loads.

In regard to the matter of upkeep, Mr. Meeker had a clear idea of what a road really requires. Let me go a little further. The railroads have been long enough in this country to have had technical attention that represents 25 to 50 per cent more work than the highways have had. A railroad cross-tie can be treated to extend its life, but a time arrives when the cost of that cross-tie is not a good investment. It is better, at some cost, to renew it and to put in a cheaper cross-tie. The same thing is true in the matter of the first cost of building highways. We had better build a cheaper road and put on watchmen to keep off the destructive loads. A 7½-ton concrete-slab road costs about $40,000 per mile in our region. It is better to keep repair gangs in maintenance service than to increase the first cost for a stronger road.

In regard to impact, all of the talk here about impact has referred to the road after it has broken down. Mr. Breed has said that impact does not amount to anything until there is a drop in the road. When we have a fault, say a 2-in. drop, it is no longer a road. Send for the section gang and do not calculate that tires or anything else will save it.

It matters not how much area of tread-contact tires have on the road; it is the total load on the axle of the wheel that counts. For brick surfaces and concrete surfaces withstand more pressure per square inch than will the rubber of the tire. It has been related here how a broken-down road was saved by putting on some asphalt. That did some good but it would have been better if a wire brush had been run across its surface, if it had been thus scraped clean and if concrete had been added. Some of the experiments that the Government is conducting relate to things long well known in civil engineering, yet this may be necessary to bring the facts sharply to the attention of the public.

As to a porous sub-base, it is a fine thing, but is it the best thing? What we are after is the best thing for the least money. To use a 4, 5 or 6-in. sub-base of sand or any other porous material, is not a good investment unless that material is easily obtainable. Where rock and sand must be hauled many miles, they are not a good investment. It is better to increase the depth of the concrete block at the same cost as that of the porous material and thus get the strength benefit of the square of the depth.

S. W. WILLIAMS:—We are not building roads in this country with any knowledge of traffic. We went before the Legislature of Ohio two years ago and asked for authority to employ a traffic and sub-soil engineer. The matter was so little understood that we could not get the necessary authority. The average road in this country is sold from the standpoint of the material salesman on the job, and not from the standpoint of the traffic. I believe Mr. Breed will agree with me that 80 per cent of the roads in this country have not been built with a knowledge of traffic conditions. We are building in some places away beyond the needs of the traffic. In other places we are building roads that do not meet the needs of the traffic. We should build roads that will take into consideration the traffic, regardless of what material the roads are built.

HARRY MEIXELL:—The State of New Jersey contains more than 500 separate and distinct governmental units. These comprise 21 counties, 235 townships, and over 250 cities, towns, villages and boroughs. In each of these governmental units there is one form or another of highway control. These local highway authorities exercise almost absolute sway over the 20,000 miles of highway which lie within the State's borders. They can improve their highways as they see fit and maintain them or not as they see fit.

This complete decentralization of highway control is the keystone to the answer of the whole problem with which we are wrestling. How can these local authorities be subordinated to intelligent centralized direction and control, or, if this is too much to ask, how can the lessons which we are learning day by day in regard to high-

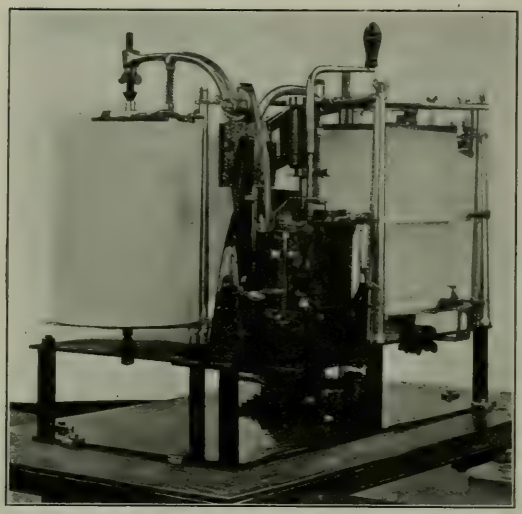


FIG. 1—A NEW FORM OF VEHICLE SEISMOGRAPH

ways be passed on to these 500 separate and distinct groups of municipal authorities?

Let us assume that to meet the highway transportation needs of New Jersey a total of 3000 miles of main arteries of travel will be necessary, although this is a very liberal estimate. Are the highway resources and energies available in New Jersey being concentrated upon these 3000 miles of highways? Is the improved road mileage being located in the very best way to meet the greatest economic demands of that State? Not a bit of it. What is being done? The 500 separate and distinct groups of highway authorities are trying frantically to obtain good roads within their own borders and in their efforts are endeavoring to reconstruct about 10,000 miles of highway. The highway authorities are not cooperating and coordinating for the accomplishment of the same definite and predetermined end. Each municipality wants good roads in its own community and, without attempting to find out whether such roads will link up with the State highway system or with the highway systems of its neighbors, it simply goes ahead and builds the roads.

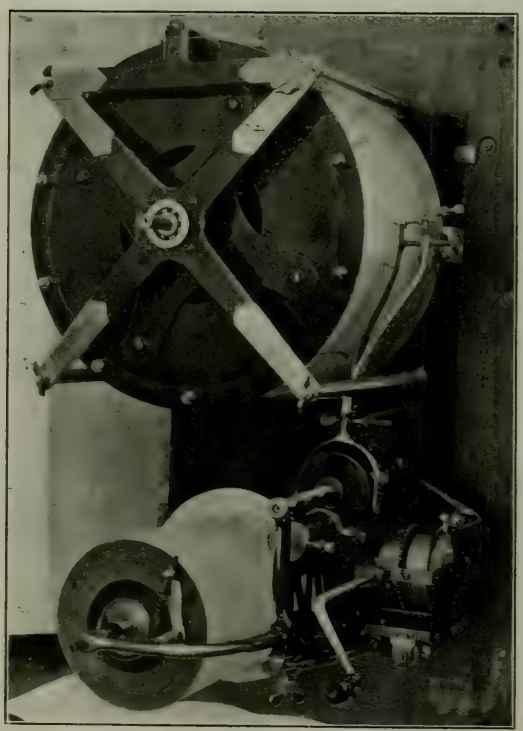


FIG. 2—VIEW LOOKING DOWN ON THE SEISMOGRAPH

For the sake of argument we will assume that a heavy-capacity improved road will cost on an average of $50,000 per mile under present conditions. At that rate the 10,000 miles of highways which the local authorities of New Jersey are striving to improve would cost $500,000,000. Since the work of highway reconstruction should be accomplished during the next decade, it is obvious that the taxpayers cannot stand such an enormous burden.

In consequence, it is imperative that legislation be enacted so that these local jurisdictions which are so numerous are deprived of their right to do as they see fit in the location of improved highways, the determination of their structural standards and in the building and maintenance of them. They should all be obliged to combine their efforts with some centralized control so that State highway systems, connections therewith and extensions thereof can be laid down to meet the greatest economic needs of the community. This is a tremendous problem to solve, but it must be solved if we are to obtain the largest possible returns from the scores of millions of dollars that are pouring into the highways of our States every year.

A MEMBER:—I cannot agree with one statement Mr. Williams made. He says, "A concrete-slab road about 8 in. thick and of a uniform depth across the road, perhaps with an increased thickness of integral supporting curb-block on the edges in some locations, is the type of road that should be built in this country." Again he says, "In my opinion the automobile vehicle world will profit by laws that prohibit anything above a 5-ton load."

The limit for any concrete road now built is about 8 in. That certainly is the practice. There are a few stretches in New Jersey and one that I know of in Ohio that are 10-in. roads. The most prominent we see out West is the Wayne County road. These roads have been standing up under the most severe loads. I believe that an 8-in. concrete road need not be restricted to 5-ton loads. There are very few road failures, compared with the enormous mileage of 8-in. concrete slabs under loads heavier than 5 tons.

MR. MEIXELL:—The International Traffic Officers' Association took Section 4 of Article 9 of the Proposed Uniform Vehicle Law endorsed by the Motor Vehicle Conference Committee and made several additions to it. The Proposed Uniform Vehicle Law recommends in the matter of restrictions as to weight 28,000 lb. gross weight for a single vehicle of four wheels or less, and advocates a maximum of 22,400 lb. on one axle and 800 lb. per in.

of tire width measured between the flanges of the rim. In addition to the requirements of the Proposed Uniform Vehicle Law, one measure specifies a gross weight limit of 40,000 lb. for a vehicle of six wheels, has a provision limiting the load on any one wheel to 11,200 lb. and recommends 600 lb. per in. of tire width for metal tires. Anyone desiring copies of the Proposed Uniform Vehicle Law and its companion measure, the Proposed Uniform Anti-Theft Law, can obtain them from the Motor Vehicle Conference Committee, 366 Madison Avenue, New York City.

W. E. WILLIAMS:—In Clayton County, Iowa, the citizens realized that their money was not sufficient to build high-class roads. They arranged to have men go out over the roads after every rainstorm and fill up the ruts by using drags and other tools. By filling up the ruts immediately after rains they keep the roads in such condition that there is a greater average use of the motor vehicle and better general highway service. That only accentuates the necessity of watching and keeping the roads in repair. We must do that. Automobile service in this country is limited to the good roads. The traveling man does not use an automobile in soliciting the country trade on account of bad roads. If we had a wider range of hard roads, the use of motor vehicles would be increased greatly.

A. F. MASURY:—The new seismograph designed by Frank Pampinella and me, although simple in construction, records a very complete and accurate history of the comparative vibration of a truck or automobile chassis under the action of different types of spring and axle-load distribution. Differences in spring action, too slight for human detection, are accurately compared. With such a means of comparison, engineers are enabled to choose with accuracy spring suspensions that will transmit the least vibration to the "sprung" portion of the chassis. The 1915 machine has been improved and developed into the present seismograph. It is sensitive to the slightest vibration and records movements that are far beyond human detection. Figs. 1, 2 and 3 and the description give an idea of the construction and operation of the instrument.

Mounted in a rigid steel frame is a metal drum 12 in. in diameter and 9 in. high, driven through a double-reduction worm and gear giving a ratio of 32 to 1. The worm shaft is driven by a flexible speedometer shaft from the front wheels, and turns the drum at the rate of one revolution per mile of travel of the truck. On the upper edge of the drum are 10 cams, equally spaced,

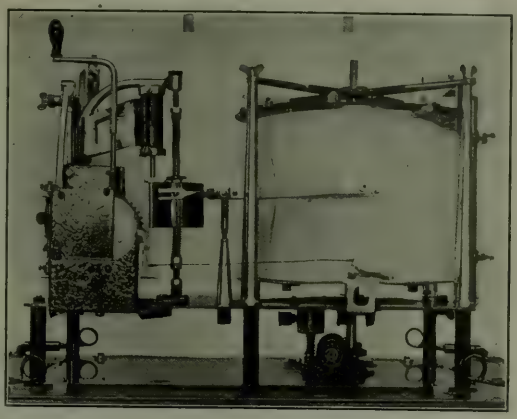


FIG. 3—SIDE VIEW SHOWING A PORTION OF A RECORD AS TRACED BY THE PENCIL

which trip a pencil-holder and record tenths of a mile on the paper which is rolled on the drum. The paper is fed to the drum from a spool at the opposite end of the frame. A phonograph motor is mounted near the recording drum and operates a pencil which marks periods of time on the record. This motor can be governed to record intervals of ½ or 1 min. as desired.

In addition to these two pencils there are two stationary pencils which rule horizontal guide lines on the paper near the top and bottom edges and equidistant from the center. The seismograph pencil is held on a light spring arm pivoted on single-point bearings. On the opposite end of this pencil arm is a slotted fork surrounding a weight which slides vertically on a central post and is actuated by the vibration of the truck. The weight is supported by a coil spring from below and a lighter coil spring above prevents excessive rebound. The weight is further damped in both directions by an air dashpot with adjustable outlets so that the damping effect can be accurately adjusted.

As the weight moves up and down, the pencil at the opposite end of the arm leaves a series of marks on the paper on the revolving drum. The proportionate length of these marks, measured from the guide lines, indicates the comparative vibration of the unsprung portion of the chassis. The entire mechanism is enclosed in a glass case

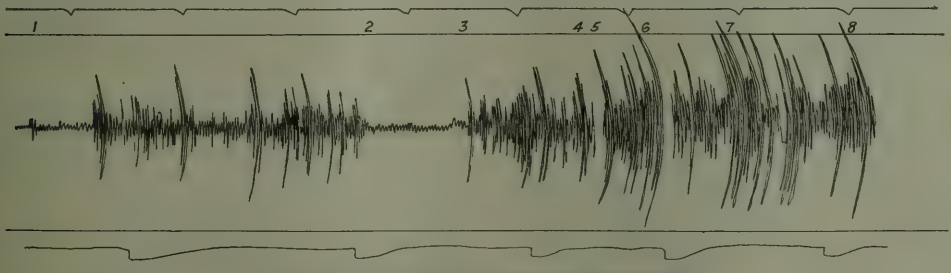


FIG. 4—A TYPICAL RECORD GIVEN BY THE SEISMOGRAPH

From 1 to 2 the Truck Was Traveling over Rough Asphalt at a Speed of 15 M.P.H., between 2 and 3 the Speed Was Reduced to 6 M.P.H. and from 3 to 4 the Speed Was Increased Again to 15 M.P.H. The Break in the Record between 4 and 5 Indicates the Stoppage of the Truck. Between 5 and 6 the Truck Was Traveling over Rough Stone Blocks on a Quay. At 6 All Four Wheels Ran over a 3-In. Obstruction at a Speed of 8 M.P.H., at 7 the Right Wheels only Passed over a Similar Obstacle at 8 M.P.H. and at 8 the Left Wheels Went over a 3-In. Obstruction at the Same Speed

with sliding doors in both the top and the sides. The seismograph is screwed to the floor of the truck or car body in any location desired, the length of the flexible driving-shaft varying with the location. A lever below the glass case throws the worm gearing out of mesh, so that the record can be stopped or started at will.

Fig. 4 shows a representative record from the seismograph as used on a 5-ton chassis, the seismograph being mounted directly over the rear axle. The numbered circles refer to the road conditions encountered, these being listed underneath the illustration. The notched line at the top of the record was made by the mileage pencil and indicates tenths of a mile. The two horizontal lines above and below the seismograph record are guide lines made by the stationary pencil and are used to measure the distance traveled by the seismograph pencil. This is preferable to a central guide line, which would be covered in many places by the seismograph record. The notched line at the bottom of the record is made by the time pencil and indicates minutes elapsed.

The company I represent has been using this instrument for some time in measuring the relative vibration in trucks equipped with standard spring-shackles and a new rubber-cushion spring-support. It has been found that over comparatively rough roads the difference is very noticeable to anyone riding on the truck, but on smooth roads the seismograph recorded a series of vibrations on the standard chassis much greater than those on the chassis equipped with the rubber cushions and which was not noticeable to observers on the trucks.

PASSENGER-AUTOMOBILE BODY-DESIGNING PROBLEMS

BY ANDREW F. JOHNSON

THE designer must know first what purpose the body is to serve, and then decide upon its exterior appearance in connection with the car as a whole. The body is only a part of the car and cannot, in the general scheme, be considered separately. After the shape has been decided upon, the designing of bodies to carry passengers is included under the heads of safety, comfort and elegance, and the factors governing each are considered briefly.

The author believes that the "best" car has not yet been built and that the time will come when the best examples of high-class passenger automobiles will not be of European origin, when the foreign builder of fine cars will tell prospective customers that his cars are as well built and as well finished as the best American car. [Printed in the April, 1921, issue of THE JOURNAL]

THE DISCUSSION

CHAIRMAN W. G. WALL:—This session is unique in that it is the first devoted exclusively to body building and design that the Society has held. The building of bodies for vehicles is an old industry, but the building of bodies for motor cars is comparatively new. Each year we find the body of the motor car becoming of more importance. In the early stages of the automotive industry it made very little difference what type of body we used; in fact almost any body was more or less satisfactory, as we were engaged then in building cars that we were glad to have run at all. Now, although chassis are still a long way from being perfect, the body is assuming more importance. From a sales angle, I would say that the body is probably the most important part of the car. Even the chassis does not offer as wide a scope to the engineering designer as does the body. While some of the bodies that we are building today are remarkably fine creations, I believe that the present basis of body design does not rest on as firm and permanent a foundation as it should. The position of the body-designing engineer is assuming greater prominence. The automotive engineer must have experience and technique, but the successful body designer must have both of these qualifications and at the same time be a true artist.

Mr. Johnson's paper brings out rather forcefully the fact that often bodies are not designed for the comfort of the passengers. The body designer necessarily meets rather a difficult proposition in that respect. There is always a certain competition between comfort and style.

There is no doubt that the chassis engineer and the body designer must work very closely together. Many of the body troubles in the past can be attributed to the chassis design. There is some question, however, as to just how rigid the chassis frame should be and how rigid the body sills or body frames should be; whether the chassis frame can take all the strain, so as to allow us to build a body with very light sills, or whether the body should be entirely self-supporting.

CAN AUTOMOBILE BODY WEIGHT BE REDUCED?

BY CHARLES A. HEERGEIST

AUTOMOBILE body building derives its origin from carriage body building, which was highly developed before automobiles were thought of. The introduction of automobile bodies fitted to a metal frame changed body builders' rules and calculations.

The influence of the metal frame is discussed briefly and the limiting sizes of body members are considered also. According to the ideas expressed, the weight of bodies can be reduced if the metal frame is designed so as to support the weight of the passengers and the body. The dead-weight also can be reduced if the frame is built in proportion to the amount of weight carried, the number of passengers and the style of bodies being considered. But in the construction of enclosed bodies, as in sedans, coaches and broughams, very little weight can be saved if stability, durability and lasting quality are to be retained. [Printed in the March, 1921, issue of THE JOURNAL]

THE DISCUSSION

GORDON BROWN:—Has any work been done with laminated woods; that is, using thin woods and binding them together with condensation products, such as condensite and bakelite?

CHAIRMAN W. G. WALL:—Do you refer to the cover for the body itself?

MR. BROWN:—Yes, to the wooden panels, to reduce their weight.

A. P. CARDWELL:—So far as I know, no one is building a body from laminated wood panels. The question has, however, been discussed a great deal. I think some panels have been built experimentally.

A MEMBER:—My company has spent about $10,000 in experimental work, largely with fiber wood products. An expert engineer in that particular line was not very successful and I was interested in knowing how the product failed. The hardest part of it was to get fabrication that would be reliable. We specified plywood for roofs. The company which was working on that particular line required a long time to get the manufacturing facilities up to the point where they could fabricate plywood and make it reliable. We found the same trouble in our experiments with plywood for the body. In fact, I think that plywood, so far as quantity production is concerned, has not yet been developed in the manufacturing process to the practical point where we can use it in bodies.

MR. BROWN:—In what respect did the product prove unreliable?

A MEMBER:—For one instance, the laminations did not knit together. The particular plywood that we used was supposed to be waterproof; waterproofed glue was used in making the laminations, but it was not waterproof, on actual factory test. Up to the time that we made our specifications, they had been brought up only to the production of comparatively small surfaces. They failed, I think, in trying to make large spreading panels. The experiment which we made with the body, which was very expensive, showed that plywood was not at all suitable. The panels were wavy and a proper surface could not be obtained on them because the fabrication was so imperfect. I understand that similar experiments have been conducted in many different automobile or body plants, but I have never come in touch with anyone who has been conducting those experiments.

LEON OTTINGER:—Regarding plywoods, certain waterproof glues are being made by the Casein Co. of America, which has a laboratory and is glad to help out the automobile trade in regard to any experimenting along the line that was just mentioned. I know that the framework of a body, made of laminated wood and waterproof glue, is being produced now in New York City, and that it has been successful. The body is covered entirely with aluminum, but the framework is all made of plywood and waterproof glue. It is claimed that in the ordinary runabout body about 65 lb. of weight is saved and that the strength is considerably greater than that of any bodies that have been built.

A MEMBER:—Is it a casein glue?

MR. OTTINGER:—Yes.

A MEMBER:—In its experiments our chemical laboratory found that the albumen glue is very much more waterproof than casein. That is what we specified. Our experiments were conducted with albumen glue; that is, blood glue.

CHAIRMAN WALL:—Laminated wood sills are certainly a good possibility.

G. H. WOODFIELD:—I had some experience with the use of haskelite roofs on sedans. This woodwork was supposed to be glued together with albumen glue, or glue made from blood. We put it through some tests. We boiled that wood for 2 or 3 days and could not boil those pieces apart; so, as our laboratory tests showed up very well, we thought we could go ahead and use it with safety. We used it on these sedans. The samples we got were fairly good but, when we got into production, it seems that they did something in preparing these panels that removed part of the softer fibers of the wood and made it porous. We could not obtain a surface on them or clean them up so that they would be smooth. Of course that made them objectionable on account of the time required to treat them with filler, rough-stuff them and paint them. We used them, however, but they developed a fine network of cracks all over and we discontinued their use because they were not satisfactory.

A. R. HOPKINS:—We have used a number of laminated roofs and find that our greatest difficulty is in the preparation of the wood paint. We find cracks developing along the joints in the wood. To date, we have no data on the proper preparation of the wood, the preliminary process that the wood must be put through to have it take rough-stuff and the necessary coating to bring about a smooth surface. We have put the roofs through the usual paint operations that we use for a steel surface but, in a number of cases, we found it necessary to scrim the entire roof to get a smooth clear paint jelly. What is the proper process to put these laminated roofs through to secure a smooth surface for the painting?

E. L. BARE:—That trouble has been experienced by several others. We found that medium-grade muslin which covers the entire roof stands up under almost all conditions and is satisfactory in that respect.

E. J. CONNOLLY:—So far as treating the wood is concerned, we have experienced much trouble with plywood for roofs, on account of cracking and not being able to paint it without waves. With this laminated stock for panels and the like, the greatest trouble has been to keep the panels from waving when going through the rubbing-deck operation. The differences in humidity cause the panels to wave more or less. There is no solution, to my knowledge, so far as body panels are concerned, because the same humidity does not exist in the factory while the different operations are being performed.

VICTOR PRESTON:—I think Mr. Heergeist's paper protected the body builders to some extent in regard to why they are not making lighter bodies today. Vehicle bodies have been built for a considerably longer period than automobiles, which accounts for the fact that recent body construction has not shown any marked degree of building lighter bodies, that point having been reached prior to the use of bodies in connection with automobiles. I think we must look for an entirely different method of body construction than that in use today if we expect to build a body much lighter and still maintain the strength and endurance required. At the Olympia Show, in London, there was on exhibition a body constructed with a framework of light steel tubing covered with aluminum panels; the manufacturer of it claimed to have reduced the weight to 50 per cent of the usual body construction, while still maintaining the strength.

In reference to plywoods and the like, during the period of making airplane parts for the Government, it was our duty to test thoroughly each batch of plywood received. So far as the practicability of waterproof glue goes, we were satisfied that it would meet the requirements; but one of the reasons that we avoid the use of plywood for body panels is the extra expense in painting them, in both time and material, over that of a metal. Plants producing large quantities of bodies are striving for as low a producing cost as possible, in addition to seeking lightness of body.

A number of car builders depend upon the body to some extent to support the chassis frame, which in my

opinion is not practicable. I have wondered as to the possibility of mounting a body on the chassis with a three-point bearing, or in such a manner as to allow the chassis frame to twist without affecting the body.

CHAIRMAN WALL:—There is no doubt that the airplane builder and designer can learn much from the body designer; there are probably a few things that the body designer can learn from the designer of airplanes. The whole basis of body construction, as it is now, depends greatly upon having the chassis frame sufficiently rigid.

F. E. MOSKOVICS:—The building of a body on an automobile chassis is a combination of ancient and modern art to about the last degree. The art of coach-building is some 400 years old; the chassis building art is young. Is it not, after all, a problem of whether we put the structural strength into the body or into the chassis? In 1896 I was working at the Daimler factory in Unter Turkheim, which is now in France. We would build a car and then some one would drive it to Paris. The chassis was designed to carry the calculated load, and it had all the strength and all the rigidity necessary to carry five passengers. We would drive to Paris and go to Kellner, Mühlbacher, Rothschild, or some other body builder, who would build on the chassis a body that also was designed structurally to carry five passengers. A man backed by 400 years of precedents in building carriage bodies is slow to accept instruction. We would give him instructions not to interfere with the spring action, the steering-wheel and the gearshift and the brake levers; then he would build the body with no mechanical cooperation between the chassis and the body engineer.

Someone suggested that if this body were built out 4 or 5 in. the passengers could be put in at the side instead of at the rear. As I see it, that was the only point of contact between the coach builder and the chassis builder up to about 4 or 5 years ago, and it is the only real structural development I have seen in body design before the advent of the very deep thin-section frames, in the case of which practically all the strains of the actual road shocks and twists are carried by the frame.

The body of one well-known car is made in three sections without any sill. The actual floor-board height above the frame is less than ¾ in. Each of the sections is bolted on the frame separately. In addition to being bolted to the frame, the rear section has an angle-iron which is bolted again with the idea of having it carry the top strains. The body is made entirely of aluminum, the only purpose of the wood used being to provide fastening bases for the aluminum panels and the upholstery. It is a very light construction and the job is very easily handled in a shop.

L. C. HILL:—Before attacking any problem of weight reduction in passenger-car bodies, it is necessary to make a careful analysis of the detail weights which constitute the total weight of a particular type. These can be grouped into three classes

(1) Parts essential to the structure, whose weight cannot be reduced materially
(2) Parts whose weight might be decreased, but at a considerable expense
(3) Parts which may be of lighter design, made of lighter material, or discarded entirely

It is the last class which deserves the study of the designer and, unfortunately, it appears to be the one holding the least promise. It must be understood that I am referring to only the particular type of body structure now in universal use. Radical designs must be resorted to if much decrease in weight is expected in the first two classes. There are details such as windshields, window glass, floor-boards and upholstery in these classes. They constitute a group which is essential and yet it is difficult to reduce their weight.

The use of airplane materials and practices in body construction has been a disappointment to many body men who were engaged in the airplane field during the war. There is a definite reason for this failure. The airplane is never expected to stand the abuse given the average car body and still maintain a high finish. It is carefully groomed by an able corps of mechanics and properly maintained at all times. Contrast this with the neglect accorded the average automobile; and yet the owner demands excellent finish and sturdy construction.

STYLE IN AUTOMOBILE BODIES

BY GEORGE J. MERCER

IT is not difficult to forecast the immediate future of the trend in automobile body models for quantity production, since quantity business necessitates a design that will please the majority and is a compromise between the old and the new. The design of an automobile body is one of the best advertising features of the car. Several factors contribute to make body changes practicable. The two preceding statements are elaborated.

The number of different body models that will prevail during the coming season is less than in past years; it includes the five-passenger touring car, the two-passenger runabout, the five-passenger sedan and the four-passenger coupe. The seven-passenger touring car and the seven-passenger sedan will be made in limited numbers.

These prevailing body types are commented upon in some detail, with special reference to style, the thought then passing to body lines that will prevail and the method of their development; the latter being illustrated by a diagram.

Minor and general considerations are discussed at some length. [Printed in the February, 1921, issue of THE JOURNAL]

THE DISCUSSION

GEORGE J. MERCER:—I understand that laminated wood is being used to form the framing of bodies and that the metal encases it. If this is practicable, and I see no reason why it is not, I think that it would be one move that would tend to produce a lighter body; also, it would eliminate some of the work necessary in framing. Those laminated parts could be made over a form that would give practically the entire contour of the body and the frame covering. It would allow some saving both in weight and in money. I do not know that this has been carried forward to any extent, but I understand that it is being tried out.

W. S. EATON:—There will be some demand for certain kinds of suburban cars, but I think the four styles

mentioned by Mr. Mercer cover the greater part of production.

CHAIRMAN W. G. WALL:—We are all striving to make automobile bodies appear low. One of the many ways of doing this is to put the brackets which hold the body 3 or 4 in. down on the frame and to make the sills vertical instead of horizontal. This makes the body appear lower, adds some rigidty to the body and reduces the weight.

H. J. WARREN:—Regarding Mr. Mercer's paper, I think the coupe and the sedan constitute little fine details. The whole tendency of the times in automobile designing is to refine details. We must have better workmanship. We must have trained mechanics. Our general results are all right, but we must require the shop workmen and factory foremen to turn out the sort of work that is wanted. Our whole trouble is in not being able to get the work done the way we would like to have it done; the way in which we designed it.

G. C. BAKER:—I come from a farming locality. In connection with the discussion about laminated panels, we have adopted a roof construction that I think has done away with all our trouble along that line. Being farmers, we naturally turned to poultry netting, as we call it. We have covered the bows supporting the roof with that, then with a layer of wadding, and then with waterproof material. We tried this as an experiment a number of years ago and found that we had no further trouble with roofs. It also eliminates the trouble with paint which some have experienced.

Mr. Mercer brought out one point on eliminating weight. He said that raising the belt moldings 2 in. has done away with a considerable number of square inches of glass. That, together with keeping the bodies low, does away with perhaps as great a percentage of weight as can be done away with in any part of the body. What success has been experienced with laminated wood as floor-board material, using a section perhaps $\frac{3}{8}$ or $\frac{1}{2}$ in. thick instead of the $\frac{3}{4}$-in. ash, or the material that most of us are using at present?

GEORGE W. KERR:—There seems to be an idea that laminated wood is a new thing. As long ago as 1885 I worked as a body-maker in Brewster's shop on Broadway, New York City, where the roofs were made of laminated wood. They made it themselves. At that time it was a long-advertised material for carriage roofs and for wagon side-panels. A company in New Jersey supplied it in any desired quantity. Dann Bros., in New Haven, Conn., at about the same time and I think continuously since then, have offered laminated wood glued up with waterproofed glue for roofs and side-panels. That was at least 25 years ago. They also used a casein glue. In 1888 I was draftsman and designer for the New Haven Carriage Co. One of the first problems that was assigned me was to find some way by which they could retrieve a few hundred phaeton bodies on which they had made the experiment of using laminated wood for the side quarters and which had appeared all right until they got on the varnish coats and were nearly ready to finish, when the surface of the wood was found to be full of fine cracks. Laminated wood never proved to be a cure for the troubles of tops or wagon panels. The wood is sawed around the log, then unfolded and used in a flat condition; this causes a rupture of the fibers of the wood, so that it is full of fine, almost invisible cracks.

In 1903 all of the Winton cars were made with mudguards of laminated wood, and so were the seat panels, both front and rear, and the doors. In 1904 the organization with which I was identified at that time made a contract with the same people who furnished the Winton to supply us with laminated panels for seats. We went through part of the season with seats made of laminated wood, but found we had to abandon it on account of its inherent disadvantages and go into the building of steel bodies. We were very early in the construction of steel bodies. I do not expect any revolutoin in the automobile body business resulting from the use of laminated wood.

As to Mr. Mercer's remarks about using laminated wood in the framework, I took that matter up with representatives of the plywood manufacturers and found that the price per square foot would be so very much greater than the price of ordinary wood that it would be absolutely prohibitive in production work to think of using plywood in place of planks.

The matter of the change of body design from time to time is really our life interest. There always is a style coming in, a style present and a style going out. It is always difficult to form a correct judgment on when to make a change and what change to make that can be coined into money. An expert on body design cannot tell by looking at a job whether it will sell or not.

The body engineer in an automobile plant is in a peculiar position; necessarily, it is subordinate to that of the chief engineer and other officials. He may conceive a design, execute it on paper and it may be the best design in the world; however, there are others who pass judgment on it who are probably very much less qualified to do so than the designer, but who have the power and the position to condemn and cast aside. Each body engineer has hanging over him the fact that his best work may not be recognized by those who are superior to him in position in the organization. The body designer must recognize the fact that in the very nature of the industry and art of body designing, he is subordinate and secondary to the chief and the chassis engineers. The mechanical engineers who designed the chassis for many years paid very little attention to the requirements of the body or to the ideas of the body designers. The latter were given a chassis of an arbitrary length and width, and had the problem of putting upon that chassis a good-looking body that would stand up. In many cases the impossible was given to them; the requirements could not be met. But time has smoothed that out considerably and the standard chassis now have dimensions which make it feasible to put on good bodies.

Regarding the stiffness of the frame which Mr. Moskovics mentioned, that frame is very stiff vertically. What provision is there in that type of frame to take care of twisting strains resulting from the irregularities of the road? The most vital problem that the body engineer has to fight is twisting strain on the body, rather than bending strain. Twisting strain is the main disintegrating force. The introduction of a chassis having the engine on three-point support, without any equivalent means of strengthening the frame against twist, results in a condition on many chassis that makes it absolutely impossible to build a sound body or one that will stand up.

On carriage bodies we had no trouble from twisting strains because there was always about the same amount of wood and metal and strength crosswise of the body that there was lengthwise. If a coach body was picked up on one corner, it would not twist 1/16 in. The springs absorbed all the road movement. In an automobile the springs absorb very little of the road movement in the case of three-point engine support; the advertising feature of the three-point-support chassis is that it does not

strain the engine. The chassis moves and allows the engine to stand still. The body is fastened to the chassis and it must twist as much as the frame does; as a consequence, everything tears to pieces. I believe body engineers ought to think, talk and fight against this, and make the chassis engineers realize that stiffness of the crankcase is the greatest factor they can use to stiffen a frame against twisting strains. There are many good examples of four-point-support engines that do not bind their crankshafts.

F. E. MOSKOVICS:—Relative to the twisting strains Mr. Kerr describes, an examination of the frame in question will show that no particular attempt is made to stiffen against them. We depend upon those strains being absorbed in a broad flexibility of the back. At the forward or cowl end there are two very rigid cross-members, one of which takes the drive of the car and the other of which supports the engine. These protect the car very effectively at that point against the twists. Out of some 16,000 cars now in existence with this construction, we have never heard of a body even being structurally loosened, much less destroyed by any of the road strains to which it is subject, through design. I believe that after all this is the best answer.

L. C. HILL:—One thing should be emphasized in connection with Mr. Forbes' paper. If there ever was an opportunity for the body engineer to make his influence felt in this industry, it is today when people cease to buy automobiles and our salesmen try to sell them. This is the time for the body engineer to show the public something better and more comfortable. The foreigners have some rather peculiar lines and curves in their body design and many of us criticize their work, but those who have had the experience of riding in an English or French-built body, have ridden in something that is comfortable. It is very important now for the body engineer to begin to use his influence and sell his management on putting in refinements in car design that will lead to comfort and appeal to the vanity of the people who buy automobiles. The body designers will not need to sell the public on innovations if they standardize on comfortable designs and adhere to them, because these designs will appeal to the public without requiring sales talk.

THE BODY ENGINEER AND HIS RELATION TO THE AUTOMOTIVE INDUSTRY

BY KINGSTON FORBES

THE field of body engineering is broader than it is ordinarily considered to be; the author's intention is to bring to the attention of the automotive industry the breadth and scope of body engineering and outline the way this side of the industry can be considered and developed.

After describing the body engineer's position, the author then discusses at some length the conflict between art and economy in this connection. He classifies a body-engineering department under the six main divisions of body construction, open and closed; sheet metal, body metal, fenders, hood, radiators and the like; trimming; top building; general hardware; painting and enameling, and comments upon each. Following this he elaborates the reasons for need of attention to details in body designing and mentions the opportunity there is at present for bringing the materials used in body construction to definite standards. [Printed in the April, 1921, issue of THE JOURNAL]

THE DISCUSSION

DAVID BEECROFT:—The attendance at this first meeting devoted entirely to the subject of automobile bodies, being over 100 persons, indicates the very great interest there is in automobile-body design. When talking of the matter of standardization with the Chairman whom we appointed from the Standards work for this year, it was decided that we should have a Body Standards Division. In the general scheme of organization the committee will be very representative.

Reverting to Mr. Hill's remarks with regard to the European body situation, at the Olympia show, in London, we received much criticism on our open-body designs. This criticism did not include our enclosed designs. Two years ago, when visiting several of the factories in France, we had similar criticisms. This past fall an English builder brought one of his automobiles to this country to try it out on our roads before going into quantity production. He brought his chauffeur with him and drove the car 4000 or 5000 miles. We sat in the back seat. The car had no foot rest and we did not need one. One trip was about 238 miles. That was an answer to the criticism the English have launched at us, that we sit on our bodies, whereas they sit *in* the bodies they make.

Two years ago the Darracq Co. was drawing some very direct comparisons with our practice in the upholstery line. I have since talked those over with some of our companies and it seems that production has stood in the way. When we ask why our automobile upholstery cannot be so arranged as to ease and hold the human body in the same way that the European upholstery does, the answer is that the Darracq and the De Lage companies have gone into a very thorough study of the human anatomy. They studied the origin of the tendons, their points of attachment and relationship; they went into a very extensive analysis of muscular movements, the positions of muscular repose and the like. All these were factors that entered into the arrangement of the upholstery and the general design. We ought to make the car as comfortable as possible, especially the rear seat. The owner and his family usually ride in the rear seat; not only do they take the wind and the bumps but all the other inconveniences. The chauffeur sits in the front seat, well hidden behind the windshield and occupying the best riding portion of the car; and now he is being protected by wings and other little devices on the windshield. We want to popularize the use of the car; so, let us make it a matter of comfort. Beginning in 1914, when we refitted our factories on a production basis, the whole problem was production. We have had in the last

few months a little opportunity to think of other things besides production, and I believe that we can accomplish something in the line of improvement.

CHAIRMAN W. G. WALL:—The point has always been made that American-built cars used in the United States had to run over such rough roads in years gone by that one could not be comfortable in any of them. Then it was not a matter of such extreme importance but, with our present road improvements, there is no doubt much truth in what Mr. Beecroft has just said.

L. L. WILLIAMS:—Body engineers have from time to time had occasion to look for certain body-engineering standards which they find are not available in the S.A.E. HANDBOOK. This applies to specifications for lumber, aluminum, sheet steel, hair, cotton fabric and other body-building materials. It seems to me there is a great need to issue, for the benefit of body engineers, something stable which we can use as a standard when we talk with these manufacturers who have been using their own judgment as to selling us what they chose and what their selling organization has said was the right thing for us to use. I think the Society ought to specify something that body engineers want to enable them to check against what the manufacturers want. Let us get some real engineering into body designing and actually set down something that we can go by. For instance, let us find out the tensile strength of cotton and other fabric for upholstery purposes and determine how long it can be expected to stand up. That is one way in which we can put this thing up to the manufacturers and make them realize that we have specific requirements. The same thing applies to sheet steel. We ought to know what it will actually stand, what the ductile quality of a piece of metal is. There are many good men here who have the information, but they seem timid and afraid to stand up here and make definite statements. They ought to stand up and make statements of fact and call everything by its right name, so that we can get body engineering on a basis equal to that of chassis engineering.

G. C. BAKER:—Perhaps the body engineer or designer is somewhat at fault himself. We have a Society of Automotive Engineers, and I think we have been a little slow about getting into it and pulling together. I joined the Society some time ago in the hope that the body engineers would get together on bodies in the same way that the chassis engineers have gotten together. The thing for us body engineers to do is to hoe our own row and not find fault with what the chassis engineer has put up to us. One of the speakers brought out the point that the engineer has suspended the engine on a three-point support, so that the engine would not be strained, and regretted the fact that this puts it up to the body designer to mount the body so that it will withstand the road jar. As body engineers we should take up our end of it and suspend the body on three points or in some different way if necessary. One speaker mentioned the fact that some method has been tried out of supporting a body so that it will swing free on a frame. These little points lead me to believe that perhaps we, as body engineers, have been as much to blame as some of the people who have put it up to us; so, let us pull together.

E. J. CONNOLLY:—When was the all-steel body first designed?

GEORGE E. GODDARD:—I cannot tell exactly. My first introduction to it was with Dodge Bros. Their first all-steel body was then in use. The first ones used in quantity production that I knew anything about were made by this company.

GEORGE W. KERR:—The first all-metal body that I ever saw was made about 1902. There were no trimming strips on the body. The trimming was all made so that it clinched under channel-iron frames.

SCHOOLS OF BODY DRAFTSMANSHIP

The principal thing that I wished to bring up in taking part in this meeting, is to make a plea for the establishment or re-establishment of the technical school of body draftsmanship. The Carriage Builders' National Association established a technical school in New York fully 25 years ago and operated it until the automobile superseded the carriage. For a brief time it was supported in some degree by this Society and its predecessor, but it was abandoned. It ought to be reinstated. There should be such a school available at a central point somewhere in the United States, where body design and body draftsmanship can be taught and developed.

In the old days the instruction in body draftsmanship was too much along an individual line. That was all right so long as it applied to carriages; when the carriage draftsmen began to go into the automobile shops, there was such a divergence in their methods from the standard methods in vogue in the drafting-rooms that it was difficult for them to become recognized as regular draftsmen. In almost every case they had to spend more or less time learning the technique of mechanical draftsmanship, so that their drawings, when turned over to the pattern-room and to the engineering departments, would be intelligible to the pattern-makers and the engineers. The line of instruction in the technical school I recommend should be designed to bring body drafting more into line with regular mechanical drafting, so that this trouble can be avoided. We have had to teach almost every body draftsman how to make mechanical drawings. There is a very essential difference between body drafting and regular engineering drafting. In almost every case the straight edge and compass will fill all requirements in mechanical drafting, but the essential basis of art in body drafting is free-hand lines that are not capable of being made with a straight edge or a compass. I wish to start a movement to get a technical school established at some central point, where this work, so worthily and so faithfully carried on by the Carriage Builders' National Association, can be carried on by the automotive industry.

CHAIRMAN WALL:—There is a great need of instruction of this kind. Could any of the present engineering technical schools be interested in the starting of such a department? Would that answer as well and could we get them to take sufficient interest to install some such course?

H. J. WARREN:—I studied in a carriage builders school some 35 years ago in New York, but when I came to build automobiles I had to learn mechanical drawing and engineering in addition. Even that was not sufficient. I have attended the two schools combined and even now find something lacking in my own knowledge and experience. A new school must be established. In the kind of school we need to have established, carriage drafting, designing, engineering, foundry practice, die-working and mechanical drawing must be taught. To establish that sort of a school we must find a principal who has been through such a school. Where can we find a man of that type who has been all through those various subjects? The suggestion is made, but how can it be carried out?

In the designing of cars the chassis engineers have ignored the body engineers completely. They have fur-

nished us with handicaps as severe as any architects could have encountered. We have made a few successes, but we have had a hard fight. When the chassis engineers begin to cooperate with us in building chassis, we will begin to see results. To produce a set of dies like the ones shown here requires a fortune. It cannot be done except in quantity production. How are small producers going to come in? They cannot do it; they have neither the time nor the money. When the chassis engineers accept the body engineers on an equal footing and allow us to work with them, we will get results. That ought to be the result of this meeting.

CHAIRMAN WALL:—The kind of discussion we have had is just what we need to assist in accomplishing results. There is no reason why all the body designers and builders should not work through the Society of Automotive Engineers.

S. J. HOWELL:—In regard to the question of establishing a body engineering school in a college, I am from a scientific school. We have what is termed the automotive engineering course. Our work in that line is looked down upon by the university; it is considered as being too specialized. The idea of the college is to give a course that will enable one to tackle the problems of engineering, but not to give the engineering problems themselves. On that account it seems to me that the scientific schools would not be willing to allow the establishment of a body-engineering course. They seem to think all the work should be entirely theoretical. If the body designers say that they want men trained in this line, the colleges might reconsider and turn out men who have some practical and general ideas of automobile engineering.

G. H. WOODFIELD:—I have experienced the same condition. I went through a school in New York City. The most successful designs I have produced have been those in which the chief engineer met me half way.

COOPERATION PRECEDENTS

C. S. RICKER:—One subject ought to be emphasized to body engineers who are not familiar with the work the chassis engineer has accomplished through the medium of this Society and the cooperation of its Sections. For example, in regard to the engine-starter and electric lights on the automobile, about 8 years ago there was just about as much cooperation between the men who were trying to find their way into the electrical equipment business and the chassis engineer, as body engineers seem to find with the average chassis engineer of today, although the two latter classes have been in contact much longer. The former two have come very close together and solved a problem that in many ways was equally difficult, if not more so, because the electrical men knew practically nothing about their own problem of handling the low-voltage electric current that was demanded on the automobile. We had in that instance a case of cooperation that has led to the present successful development in electric lighting for motor cars.

Another case of the same kind of cooperation is to be found now between the fuel men and the chassis engineer. It would be practically impossible to make a car perform properly if the chassis engineer did not concede something to the carbureter man and if he, in turn, did not give something to the chassis man to obtain an operable utility for public use. In the case of the body engineer, I think he will find that he can get close cooperation from the manufacturer. Many of the engineers who have appreciated the body-builders' problem are designing deep chassis frames now. On at least 10 cars, within the last 2 years, the depth of the chassis frames has been increased from 1 to 3 in. to provide a more adequate support for the body. Again, the chassis engineer has been widening the frame and locating the springs beneath it, so that the channels would not twist with the spring action, thus providing a solid foundation upon which to place the body. In the support of the body the chassis engineer must have a kick-up in the frame at the rear end, to allow for spring action and provide the easy riding qualities that are demanded by the public. The cushions alone are not sufficient for this purpose. The carrying of a body sill over the frame kick-up also weakens the back end of the body. Efforts therefore were made to avoid these difficulties. For example, I have seen one frame on which the sills are absolutely straight, run along the side of the kick-up and are supported on brackets attached to the frame side-rail. Working this problem out in another way also helped the body engineer. This sill construction was made necessary by the manufacturing methods in the plant where I saw it. They did all their own painting and carried all the bodies through the ovens on flat chain conveyors. They also flowed all the color, prime and varnish, over their bodies. They found that with the kick-up it was difficult to handle the body on conveyor mechanisms without special supports and that was one of the chief reasons why they went to a straight flat sill the entire length of the body.

M. W. GAFFNEY:—I have had some experience within the past year in body designing and mechanical drafting. I find no difficulty whatever in breaking in good draftsmen for body drawing. I am willing to instruct these young men and they learn very quickly. I see no reason why we should be worried about that. A man with brains ought to be able to take up such work quickly. I see no reason for establishing a school. Such a school was all right in its day, but it has outlived its usefulness.

MR. GODDARD:—In one case where we had 23 different types of body, the drafting was a large problem. We subdivided it. The full-size draft from which the body was made was handled in a separate drafting department. It had its own sample body shop in which to make samples and test out the drafts before turning them over to the production department. We also had another division of the body-drafting department which took care of all hardware and such units as folding seats, foot-rails, robe-rails, hinges and locks. That class of work can be handled by mechanical draftsmen very well. The mechanical drafting division, as it might be called, also took care of the rear fenders, which are properly part of the body work. In our wood-frame construction we used the metal wheel-housing, which was handled by the mechanical drafting department, as well as the windshield and top parts such as sockets and the like. In order for them to work with the drafting department which made the full-sized drafts of the body itself, we found it necessary to make what we called a master layout. This was a special drawing or drawings showing the surfaces to which they had to work. For instance, we would take a portion of the body from the rear door-hinge pillar back to the center of the tonneau, working of course from the same points originally established on the master full-sized draft. We would lay out the shape, for instance, of the wheel-housing line; in other words, the line which the rear fender must fit up to. In that way the mechanical drafting division could work out their detailed drawings of the metal wheel-housings, seat panels and the fenders, such as a pattern-maker and the machine shop would use.

When the wheel-housings and fenders were assembled in the body, they fitted perfectly. The whole automobile body subject is a complex one, but it merely requires organization and subdivision. I have outlined the way the problem can be handled where bodies are designed and built in the same plant as the chassis. The idea of dividing the work and making the men specialists in their particular line of work may be helpful in the consideration of the problem.

MR. KERR:—Some remarks have been made that I dislike to have remain as the last word on the matter of a body-engineering school. The typical attitude of the mechanical engineer toward body designing and the body engineer was expressed; it is that anyone can do it. We who are regular body designers have spent our lives in acquiring something that the ordinary mechanical draftsman does not have an opportunity to work on. One of the qualifications for doing a poor job and a cheap job is ignorance of the subject. If we want to make the cheapest thing that can be made, the less we know about that thing the better, because our ignorance will lead us just a little way and there we will stop. The fact that all of the well-known carriage designers were drafted into the automobile business, after the regular automobile designers had come to realize that they were deficient on a certain subject, shows that the automobile-body draftsman and designer had something that they did not have. It is to perpetuate that something and carry it on, and make body draftsmanship a desirable thing to learn and a thing that will be continued, that I advocate the establishment of a school of body design. There is something in this body-designing business that the ordinary mechanical draftsman does not get in the schools through which he passes.

KINGSTON FORBES:—With reference to Mr. Mercer's remarks on laminated wood or wood-panel bodies, these require more time to make than the present style of wood-frame and metal-covered bodies. They require also equipment which takes up much space that would be out of the question in large-production manufacturing. This point is demonstrated by the manufacturer of the laminated wood roofs for closed bodies which require special equipment and large presses. It is also a harder and longer job to paint a wood body.

With reference to the ancient art of carriage building mentioned by Mr. Moskovics, very little of the 400 years of precedent is exemplified by the modern motor-car body. For example, the all-steel enamelled body is entirely a modern conception. In the last few years almost every form of construction that could be considered for an automobile body has been tried out and, so far, the solid-unit construction is found to be the most widely practicable and this is a combination of metal and wood. The real body development has been in the closed-car body, and this cannot be built up of different sections very conveniently. The closed car was primarily built for city use, but today the owner would be surprised if he could not drive his closed car 40 m.p.h. or over. If it rattles or creaks, he turns it over to the shop. To my mind the closed car of today is the real demonstration of every builder's progress in the art.

Mr. Hill brought out some important ideas in regard to the sacrifice of convenience and comfort in American cars. I think he takes rather an unfair advantage of the American body-engineer. In the first place, road conditions are entirely different in Europe from what they are in America. On the average road found in the United States, the passenger finds more comfort and ease in the straight sitting position of the American car than he could in the inclined position on some of the foreign cars. The average European car is in the cyclecar class; the larger cars are nearly all equipped with special bodies and no two of them are the same. Much of the hard-riding quality that can be justifiably complained of is caused by the rapid production methods in building, where the original shaped designs for the upholstery are lost sight of. There is one other point to be considered, which is that all-around riding comfort cannot be tested by taking show-room rides. Many cars which appear very luxurious in the show-room are not all desirable under average touring conditions.

A. F. JOHNSON:—In reference to the art and craft of vehicle body building, it is actually much more than 400 years old. In the World on Wheels, page 211, we read that

> As early as 1294 A.D., by an ordinance of Phillip the Fair, of France, for suppressing luxury, citizens' wives were forbidden the use of carriages, under heavy penalties; but this restriction was not long continued.

Further, quoting from Rondo, page 457,

> Up to the time of Charles VII, of France, in 1457 A.D., carriages were set directly upon the axles; but in that year Ladislas V, King of Hungary, gave a coach to the French Queen. This coach was much admired by the Court and by the people of Paris.

This presumably was because the coach was suspended on leather straps, as steel springs were then unknown.

NEED FOR RESEARCHES ON AUTOMOBILE PARTS

BY WILLIAM T. MAGRUDER

THE time has come when greater attention must be given to the smaller parts and the various appliances found on automotive machinery. Previously, investigations have been made by the research laboratories of a few companies manufacturing engines, carbureters and some other parts, but chiefly engines; by the laboratories of research corporations, including the Bureau of Standards and the Bureau of Mines; and by the engineering laboratories of colleges and technical schools.

The number and value of the researches that can be conducted and reported on from time to time by these agencies depend entirely upon the appropriations that they can obtain by act of legislation and upon the personnel of the staff that can be attracted by the opportunity to do this class of work. It would therefore seem to be to the interest of automotive engineers to advance the research work being done by Federal and State institutions, to see to it that adequate appropriations are made by Congress and the State legislatures and that those problems which need solution be attacked according to a guided program.

The author gives an account of engine tests made at Ohio State University, inclusive of considerable infor-

mation regarding the kind of research, methods, equipment and results. A further series of tests to determine power lost in transmission is described and commented upon in a similar manner, and mention is made of a series of tests which it is proposed to conduct to determine the power required to drive a car at different speeds. [Printed in the March, 1921, issue of THE JOURNAL]

A NEW PRINCIPLE OF ENGINE SUSPENSION

BY S. E. SLOCUM

AMONG new developments in the automotive field there is none which offers greater possibilities than the redesign of the engine suspension to eliminate vibration. The problem of overcoming vibration is related closely to the fuel problem, for vibration is responsible for a much greater loss of power and a consequent increase in fuel consumption than ordinarily is supposed. The common impression seems to be that, while vibration is undesirable, it absorbs but a small amount of power. This is not substantiated by actual facts.

Two instances are given to show what large power losses may result from vibration in certain cases. One is that of an automobile engine which had a badly balanced crankshaft; the other, an experiment with an electric motor mounted on a wooden table, the idea being to reproduce the condition of a machine mounted on the upper floor of an ordinary wooden building.

After a description of these two studies, the thought passes to other disastrous effects of excessive vibration and the consideration of critical speeds at which the most serious losses due to vibration occur.

The causes and types of vibration and the elimination of vibrations due to synchronism are discussed in considerable detail, followed by an illustration and account of one method of applying this principle to automotive apparatus. [Printed in the January, 1921, issue of THE JOURNAL]

A SUGGESTED RATING RULE FOR RACING CARS

BY H. M. CRANE

IN recent years automobile engines for racing purposes have been very generally rated in accordance with their piston displacement. The natural result has been to encourage the highest possible engine speeds to attain the greatest possible piston displacement per minute. Features of engine design that have been developed under this rule include enormous valve areas, usually obtained by a multiplicity of valves, huge inlet pipes and carbureters, extreme valve-timing and very light reciprocating parts, all of which are undesirable in commercial engines.

To encourage the design of engines of a type developing higher efficiency at lower engine speeds, the suggestion is made that a rule be formulated under which cars will be rated in accordance with the piston displacement per mile actually used by them. Such a rule would involve rear-wheel diameter and gear ratio, as well as the piston displacement of the engine. This would automatically allow the use of engines of varying size, provided the other elements were proportioned properly. [Printed in the February, 1921, issue of THE JOURNAL]

TORSIONAL STRENGTH OF MULTIPLE-SPLINED SHAFTS

BY C. W. SPICER

THE results of some tests recently completed are presented. No attempt is made to develop the theory involved. It is intended to describe only the actual tests, the conditions under which they were carried out and the results obtained.

Superficially, it would seem obvious that the torsional strength of a multiple-splined shaft is greater than that of a full round shaft having a diameter equal to the small diameter of the splined shaft. Data on this and related questions were sought experimentally. A series of tests was run on 15 carefully machined shafts. The dimensions shown are the actual ones of the test-pieces, there not being more than 0.0005-in. variation in any shaft from the diameters shown. Heat-treating was very carefully carried out, and each specimen carefully checked by Brinell instrument on the ends and by scleroscope throughout the length. The Brinell numbers were all between 220 and 235, and the extremes of scleroscope hardness were 38 and 43. The testing machine and a composite curve of test results are shown. [Printed in the February, 1921, issue of THE JOURNAL]

ECONOMY AND PERFORMANCE DEMANDS

BY J. G. VINCENT

STATING that economy and performance are diametrically opposed in that the greater the performance demanded the less the economy is likely to be, the author mentions that the gasoline bill of the average user is not the major portion of his expense and asserts that economy is determined very largely by the engine design, the chassis design and the tires. The subject of engine design is outlined and consideration is given to acceleration during periods of coasting.

Discussing briefly the chassis and the tires, attention is given to oil and tire economy, followed by statements regarding design from the viewpoint of service and performance as influenced by gear-ratios and gear-shifting. [Printed in this issue of THE JOURNAL]

CHASSIS DESIGN FOR FUEL ECONOMY

BY A. L. PUTNAM

AS the engine is the most important unit of a complete automobile chassis, it has had a major share of attention in its development and is far in advance of the rest of the machine as a result. Consequently, at least for the passenger-car engineer, improvements in the automobile as a road vehicle offer greater scope and reward than improvements in engines, particularly as all such improvements are reflected in direct proportion instead of being minimized by adverse operating conditions. The attitude has been common of not worrying about a fraction of 1 per cent loss here and there when such an enormous loss occurs at the exhaust pipe and radiator. Other varying and intermittent losses in the aggregate are not insignificant and, when multiplied by millions of cars, become millions of gallons of fuel and oil.

The author's aim is to call attention to some of these losses, with suggestions as to means and methods of correction. This includes a study of the effects of heavy greases, dragging brakes, relative motion of parts and tire sizes, all of which are discussed at some length. [Printed in the February, 1921, issue of THE JOURNAL]

THE DISCUSSION

CHAIRMAN H. M. CRANE:—My paper entitled A Suggested Rating Rule for Racing Cars[1], states all that I have to say on this subject. I hope the engineers in the automotive industry will do some thinking along those lines, for I believe they might in this way learn more by racing than they are apt to learn under the present rule.

This meeting was called primarily to bring out questions that have come up in our various conferences on fuel with the members of the petroleum industry. We have been under a constant fire from the other side, on the question of why we use so much gasoline. When I first began using gasoline, about 1898, the producers did not worry about how much we used; in fact, they worried about how little we used. However, they have put a strong burden of proof on the engineers in this industry to show why we should not reduce our consumption per passenger-mile and per ton-mile. The greatest and most spectacular gains in this direction can be made in engine design and in a most interesting line of work. On the other hand, we must not overlook the fact that those gains are simply in the production of power, and that we must show also that we are not using more power to accomplish results than is justified.

The petroleum industry has taken a certain point of view regarding the use of the small car, that I think deserves comment. The automobile is supplied to give service; if it is a truck, it must carry tonnage; if it is a passenger car, it must carry passengers. Part of the service in carrying passengers lies in the speed at which the passenger cars are operated and the comfort in which the passengers are transported. We have no right to overlook these facts. We are called upon to give the public comfort and speedy transportation, even if this uses somewhat more gasoline than slower or less comfortable transportation. For instance, I think we cannot ask the public to use open cars without tops or windshields, simply because they require less gasoline to drive than sedans or limousines. In that case, we would not be giving service to the public.

[1]See THE JOURNAL, February, 1921 p. 118.

I will speak of several points regarding chassis design to illustrate what I have in mind regarding the possibilities in that direction. We have been asked by the petroleum industry why we use such high-geared cars; why the public is given cars that can go everywhere, almost, on high gear. The public does want such cars, but is it not for the reason that gearshifting today is largely a matter of strengh and acrobatics? We have made gearshifting so difficult that the use of the lower gears is confined to starting and times when progress cannot be made in any other way. Unfortunately, the design of the present type of engine is such that the very means we use to cut down its power, throttling, also reduces its economy. I was told of some very interesting tests that had been made to illustrate this fact. On a flat track a car would make the best mileage per gallon if opened up wide for a given distance, accelerated to a fairly high speed and then allowed to coast for a given distance with the engine shut off. That is a very clear illustration of what I mean. Theoretically, that should not be the case so far as the resistance of the car is concerned, because the resistance of a car to propulsion is not in the form of a straight-line curve, but goes up very rapidly with increase of speed; and, the higher the speed is, the more rapidly it goes up.

Another phase in which many of our smaller cars are deficient is the braking. The brakes are partially applied all the time, and no reasonable means is provided for the average owner to keep them properly adjusted so as to hold when he wants them to hold and yet not drag when that is not desired. Another feature, common in some of the cheaper cars, is the defects of gearbox and rear-axle design. These gearboxes and axles are designed in such a way that oil cannot be used for lubrication. Grease of a heavy character is required, for oil will escape so rapidly that the gearboxes rapidly become dry and the cost of operation with oil too great. In high-speed apparatus, such as the automobile rear-axle and gearbox, grease is a very poor lubricant. It also absorbs a large amount of power in operation. In other words, many probably had experience in the old days with cars whose gears could not be shifted on a cold morning and yet after running for a time could be shifted easily. That was partly due to the heat of the engine but, also because the churning of the grease produced heat and power was required to produce it.

I have sketched a few points that enter into the big problem of economy of service. I say "service," as against economy of operation, because economy of operation only goes part way. We must give the owner service and at the cheapest price. Part of the service, as I said, is in speed and comfort.

I am glad that Mr. Putnam put so much emphasis on the tire question. The tire companies have failed in their literature to begin to take advantage of the possibilities of the cord tire. They have recommended pressures that produce exactly the results Mr. Putnam has outlined. For obvious reasons the cord tire is a big improvement over the fabric tire in efficiency. The efficiency of any spring is the amount of energy that it will return, compared with the amount put into it. The fabric tire is inherently a shock-absorber, and that is the cause of its relatively great self-destruction; being a shock-

TABLE 1—PISTON DISPLACEMENT PER MILE PER POUND OF TOTAL CAR-WEIGHT AND PER POUND OF PASSENGER-WEIGHT

Column			1		2	3	4	5	6	7	8	9	10	11	12	13	14
Designation	Car Type	No. of Cylinders	Bore, in.	Stroke, in.	Piston Displacement, cu. in.	Tire Size, in.	Tire Revolutions per Mile	Gear-Ratio on Direct Drive	Fuel Inspired, cu. in. per mile	Weight with Complete Equipment, Tanks Full, lb.	Number of Passengers	Total Weight with 150-lb. Passengers, lb.	Percentage of Passenger to Total Weight	Cubic Inches per Mile per Pound of Total Weight	Cubic Inches per Mile per Pound of Passenger-Weight	Assumed Mileage per Gallon	Col. 12 Divided by Col. 13
A	Ordinary	12	3	5	424.1	35	576.2	4.36 to 1	532,720	4,746	7	5,796	18.1	91.91	507.35	....	.....
B	Ordinary	8	3 1/8	5 1/8	314.4	35	576.2	5.07 to 1	459,324	4,035	7	5,085	20.6	90.33	437.45	10.0	43.74
C	Large	6	3 1/2	5 1/4	303.1	33	611.2	4.33 to 1	401,385	3,690	7	4,740	22.2	84.68	382.27	....	.....
D	Small	6	3 1/8	4 1/4	195.6	33	611.2	4.63 to 1	277,149	2,600	5	3,350	22.4	82.73	369.53	....	.....
E	Large	4	3 3/4	6 3/4	298.2	32	630.2	3.87 to 1	364,098	4 030	6	4,930	18.2	73.85	404.55	12.5	32.36
F	Small	4	3 1/4	5 1/2	182.5	32	630.2	4.87 to 1	280,344	2,640	5	3,390	22.1	82.70	373.79	20.0	18.69
G	Motorcycle with Side-Car	2	3 5/16	3 1/2	60.3	28	720.3	4.91 to 1	106,701	563	2	863	34.8	123.64	355.67	35.0	10.16

absorber, it absorbes energy and over-heats. The difficulties that Mr. Putnam outlined come from very plain causes. In the rear axle, especially, we have a heavy weight swung between two sets of springs and, unless it is damped in some way, it will acquire, under certain conditions, some very remarkable activities when the periods of the two sets of springs get into certain relation.

AUSTIN M. WOLF:—Mr. Crane's suggested rating rule for racing cars is a very meritorious one and it should result in increasing the efficiency of the car as a whole, in that everything else will be taken into consideration and receive as much attention as the engine receives today. We picture engines and nothing else when we think of racing cars, and neglect to a large extent the rest of the chassis. Limiting a car to a certain piston displacement will develop an engine that is good for only high and constant speed. This, as Mr. Crane says, is not the commercial engine we desire for automobile use.

I think that Mr. Crane's suggestion can be applied to advantage in our present-day production of cars, carrying the displacement to a weight basis, and while the figures I give are susceptible of various interpretations, they nevertheless bring out some interesting facts. What I propose to do is to consider the piston displacement per mile per pound of total weight of the loaded car and per pound of passenger-weight. I have divided the cubic inches of piston displacement per mile by two, in that the result would be the amount of charge that the four-cycle engine would draw in through the carbureter. The relative value of the figures remains the same nevertheless, and this figure could be used in determining the theoretical fuel consumption on a basis of air to fuel ratio.

Table 1 lists representative touring cars and also a motorcycle with a side-car. A summary is given of the cylinder size, the piston displacement in cubic inches, the tire size, the revolutions of the tire per mile, the gear-ratio, the cubic inches per mile inspired through the carbureter, the weight of the car ready for the road with complete equipment and the tanks full, the number of passengers, the total weight, the percentage of the passenger to the total weight, the cubic inches per mile per pound of total weight, and the cubic inches per mile per pound of passenger-weight.

It is interesting to note that, on a basis of total weight, the motorcycle consumes a greater number of cubic inches than any of the cars. However, due to the fact that the passenger load constitutes 35 per cent of the total weight, we find that the motorcycle obtains the best performance on a basis of cubic inches per pound of passenger-weight. This is an argument for reducing the weight of our cars. As Table 1 shows, the passenger load constitutes from 18 to 22 per cent of the total load.

The effect on the gear-ratio is very noticeable in the case of Car E. For its size this car consumes the smallest number of cubic inches per pound of total weight of any of the vehicles mentioned, and in the cubic inches per pound of passenger-weight it shows a very creditable figure. The table is, of course, based on the rated capacity of the manufacturer. Referring to Car E, there is no doubt that a seven-passenger model could be built that would weigh the same as the six-passenger type. In this event the cubic inches per pound of total weight would be 71.67, and the cubic inches per mile per pound of passenger-weight 346.75, which is the best figure of any under Column 12. The effect of a high gear-ratio is thus brought out, in line with the findings of Mr. Nelson in his paper on the Fuel Problem in Relation to Engineering Viewpoint.[2] The figures in Table 1 assume, of course, that the efficiency of the carbureter, engine, transmission, axle, tires and the like, is equal in all cases and that all losses are the same. This, however, is not the case and probably a factor which is the readiest criterion would be the miles per gallon of fuel consumed. There still would be some variables such as atmospheric conditions, road and wind resistance and kind of fuel. If we divide the figure that is obtained in Column 12 by the number of miles per gallon, we obtain another result that is very interesting. We assume that the vehicle obtains the number of miles per gallon of fuel given in Column 13. The results in Column 14 show what light-weight construction can do, as in the case of a motorcycle.

[2] See THE JOURNAL, February, 1921, p. 101.

W. P. KENNEDY:—I am presenting this communication on behalf of Col. A. J. Slade, who was in Europe during the war period as Chief of the Engineering Division of the Motor Transport Corps and, as a member of the International Armistice Commission, went into Germany to take over the German trucks. He was impressed while over there with the desirability of using light cars for courier service and, in collecting the German trucks, took advantage of this opportunity to send back three models of very light car which had been used by the Germans in courier service and which have since been in Baltimore. He recently communicated with the Engineering Section at the Motor Transport Depot, Camp Holabird, Baltimore, Md., asking what disposition had been made of these three machines and whether any progress was being made in taking advantage of them in the camps, in applying them to military service. The communication from W. T. Norton, chief of the engineering branch, Motor Transport Corps, is as follows:

> Relative to small German passenger cars, this section has at present three such cars; namely, a Mathias, a Benz and a Wanderer. The Wanderer car has been rebuilt and is in courier service between Camp Holabird, Md., and Washington, averaging 110 miles per day. The Mathias car is being rebuilt and probably will be put in the same service in the near future.
>
> The general idea of testing out these cars is to see if there is any possibility of doing away with the heavy motorcycle and side-car which has been used previously for mail courier service. The maintenance of the heavy motorcycle and side-car in this kind of service is excessive and the tests which we have conducted so far indicate that a car of the Wanderer type will be more economical to maintain and more reliable.
>
> In the event that cars of the Wanderer and the Mathias types test out successfully, it is believed that these vehicles should be Americanized. The track should be increased from 48 to 55 or 56 in. and the general design changed to make the various units more accessible. The present German designs are such that repair work on any of the units is very difficult, requiring considerable time and labor.

JOHN YOUNGER:—I did a good deal of work on splined shafts from 1913 to 1915 and embodied the results in a paper presented before the American Society of Mechanical Engineers.[3] This paper shows the effects of different heat-treatments on splined shafts, the effects of several alloy steels and also the effects of various diameters on the central portion of the shaft. I think it proves conclusively, as does Mr. Spicer, that the strength of the shaft with splined ends is the same as the calculated strength of the smallest diameter at the bottom of the spline. Reference is given in my paper, in connection with some of the tables, to part of C. E. Garrard's study of splined shafts made several years before. It seems to me that a bibliographical list of such papers should be compiled.

C. W. SPICER:—Attention should be called to the fact that the experiments reported on in my paper indicate that the strength of a splined shaft is even *less than* the strength of a full-round shaft of diameter equal to the smallest diameter of the spline. To be specific, the difference in this particular case amounts to an average of 18 per cent. This discrepancy is of sufficient importance to be taken into consideration when making careful calculations.

CHAIRMAN CRANE:—I do not know whether Mr. Spicer has had an opportunity to go into the effect of repeated stress on splined shafts, but the tendency is distinctly to enhance the effect he has found on a straight torsional test, especially if the fillets in the corners of the splines are not amply great. We had a shaft break in torsion under those conditions. It looked like a perfectly good pie cut into segments, with cracks leading from the center to the corners of the splines. Of course, what happened was that the metal of the spline actually aided in overloading the already highly stressed metal on the surface of the round part of the shaft. I hope that, if Mr. Spicer has made equivalent tests on various sizes of squared shaft, he will give us the benefit of them at this or at some later date.

PROF. S. E. SLOCUM:—The main object of the type of suspension described in my paper is to relieve the chassis from the vibration ordinarily transmitted to it by the engine. It is not necessary, in this connection, to discuss what produces vibration of the engine, but only to consider the effect of vibration on the chassis. Whenever the speed of the engine falls into step with the natural frequency of vibration of the chassis or of the body, the vibration is greatly intensified; in other words, whenever we have synchronism between the engine and the chassis we have those excessive vibrations known as periods. If it were not for this synchronism between the engine and the chassis, the average person would scarcely know there is any such thing as vibration. Therefore, relieving the chassis of vibration is very largely a question of destroying synchronism between the engine and the chassis.

There are a number of distinct effects of vibration on the chassis. There is, of course, a considerable loss of power. We hope to have soon some experimental data that will show exactly how great that is. Vibration tends to produce fatigue of the material and, with the ordinary type of rigid engine-mounting, this matter has to be taken care of in designing the chassis. From the buyer's standpoint the greatest objection to vibration it its unpleasant effect on the passengers.

The principle underlying this new type of suspension consists in employing a three-point mounting of the engine, one of these three points being rigid and the other two being resilient. The effect is to permit a certain vibration of the engine within small limits, about any axis passing through this fixed point. The engine is insulated from the chassis in a sense, so far as vibration is concerned. It is free to vibrate with a very small amplitude, without transmitting that vibration to the chassis or to the body. By properly designing these resilient supports, we can make sure that the period of these resilient supports is different from the period of the engine and also from the natural periods of the chassis, and in that way we can destroy synchronism which is responsible for most of our vibration trouble.

There are many different ways in which this principle can be applied. In Fig. 1 of my paper the principle is applied by mounting the engine in a sub-frame or cradle, and suspending this cradle from the chassis with a three-point suspension, the rigid support in this case being directly under the transmission and the two resilient supports being at the forward end of the engine, one on each side. In this particular application, the two outer members shown in Fig. 1 represent the two rails of the chassis. The engine is mounted in the sub-frame, just within the two channels of the chassis. The rigid point in this case is placed directly under the transmission and consists of a ball-and-socket joint or its equivalent. The two resilient supports are placed at the forward end of

[3] See *Transactions of the American Society of Mechanical Engineers*, vol. 39, p. 355.

the engine. That gives a three-point support for the cradle. The engine can be mounted upon this cradle in any way that appears desirable. The point is that the engine, together with the cradle, is free to oscillate about any axis through the fixed point. The extent of the oscillation is controlled by designing the resilient supports so as to permit vibration of a very small amplitude, but also so that the supports will be very rigid as regards shock.

MR. WOLF:—Will Professor Slocum state why the rigid support of the suspension system he described is located under the transmission? Is there any particular reason?

PROFESSOR SLOCUM:—The idea is to minimize motion of the brake-lever or the gearshifting lever, but the whole suspension can be reversed just as well, and the fixed point placed in front and the springs in the rear; or any other combination that seems best for a particular engine is feasible. The thing is to adapt the principle to the engines as they are at present. The most practical, although not the ideal, way seems to be to mount them in a cradle as shown.

JOHN G. PERRIN:—I cannot say that we have much to learn from what I saw recently in Europe. We have heard much about the wonderful economy obtained there but, although perhaps we might find some modifications in the engines or cars, my conclusion is that there is nothing radical in that respect. They obtain the high economies we hear about with small cars, such as would not be adapted to use in this country unless we got over the idea of wanting to do everything on high-gear. The so-called small cars have about a 48-in. track. We found that absolutely unsuitable to American conditions, except in sections where the roads were very highly improved. The engines are practically not different from ours. They are using a great number of I-head engines, but there is still a greater number of L-head engines. They are improving in a number of detail that we have found advantageous, such as making the pockets in the combustion-chamber as small as possible and using a good lubricating system. Their carbureters have no wonderful or mysterious features that are not embodied in our own best carbureters. They obtain light weight by building small cars. We have done that, but have found it impracticable for the market. Their large cars attain no better fuel economy than our own best cars. For one thing, they use cars of higher gear-ratios. We have found such gear-ratios unsuitable for our purposes, because we want to do everything on high-gear. We all know that high gear-ratios promote fuel economy. Their connecting-rods are better than ours and they can maintain longer periods of driving on their direct drives, thereby getting better fuel economy.

In regard to advanced design, there was nothing very remarkable, except the Ricardo engine that is being produced now. It was used during the war in a number of tanks. Much is claimed for it in a number of ways. It has a very long piston, in two sections; one acts like an ordinary piston and the other as a guide for it. They claim elimination of all condensation of fuel in the crankcase, better lubrication and avoidance of much of the piston friction. I believe that insufficient attention is paid to the losses in piston friction. Designers try to reduce engine weight by using short connecting-rods and thereby add a great amount to the piston friction losses.

The British builders are paying much attention to the small cars, but I could not see that their market is suitable for them. Very small clearance is allowable on the English roads and they certainly can reduce weights a great deal. A small engine will propel five people around very satisfactorily. Their small engines are rated at 11 or 12 hp. One very dominant reason for bringing the horsepower down and using the smaller sizes of engine is the tax of £1 per horsepower, which is of course a considerable burden to car owners.

Their mileage per gallon of fuel is based on a better grade of gasoline than we use ordinarily. It is similar to the grade of gasoline we were getting 4 or 5 years ago. Their gallon is the Imperial gallon, which is larger than our gallon; six of our gallons are needed to make five of theirs.

In their high-priced cars there is a tendency to incorporate a number of airplane-engine features, such as aluminum cylinders with steel inserted sleeves. I do not see that we have anything to learn from European practice. We are further along, I believe, in solving the fuel-economy problem and, judging from all I have heard here today and from what I know is going on around the country, we are certainly attempting reduction of weight much more actively and to better advantage.

LEE W. OLDFIELD:—While in France, after the armistice, I had occasion to use one of the Wanderer cars and also to make rather extensive tests with a Petit Peugeot car. Each of these cars has a four-cylinder engine of 60-mm. bore and 90-mm. stroke. The only detail of construction on the Wanderer car that is particularly interesting is that the transmission case is made of steel stampings.

With regard to economy and performance, the Petit Peugeot, which is a slightly smaller car, had a very much better performance than the German Wanderer car. I drove a Petit Peugeot from Paris to Clermont-Ferrand. On one particular stretch, a distance of about 70 miles, we made an average of 28 m.p.h. for about 2 hr. 18 min. with this little car. It rode very comfortably. The fuel consumption was at the rate of slightly less than 7 liters per 100 km., which works out very close to 35 miles per gal. There were no details of particular interest in the engine of either of these cars. They were both magneto-equipped and, generally speaking, of standard accepted design. The Wanderer had silent chains for the front-end drive and the Petit Peugeot had a set of fiber gears.

MR. OLDFIELD:—The Petit Peugeot behaved remarkably and will run astonishingly fast. It has direct drive on both second and third speeds. The car is very nearly as fast on second speed as it is on third; I should say there is not a difference of more than 10 m.p.h. One becomes nervous when driving wide-open in second speed, expecting a number of parts to come up into one's lap, but the car continues to go. The gear-ratio is about 7 to 1 on second and slightly better than 3½ to 1 on third speed, with about a 21-in. wheel. I believe the Wanderer car uses a 28-in. wheel. It did not ride or stay on the ground as well as the Petit Peugeot, although it is a car of 100-in. wheelbase, whereas the Petit Peugeot wheelbase does not exceed 60 in.

MR. MANLY:—What is the weight of the Peugeot car?

MR. OLDFIELD:—About 1300 lb., with the load.

CHAIRMAN CRANE:—That comparison of two small cars is very interesting, but I would like to have those present figure the ton-miles per gallon of the Petit Peugeot on the basis of 30 miles per gal. and 1300-lb. car weight. It is easily possible in this country, with cars having maximum acceleration, to do 30 ton-miles per gal. On the basis of 1300-lb. car weight, even allowing somewhat extra for two passengers, this car was not

doing much over 20 ton-miles per gal. and, after all, the ton-miles per gallon is the real solution as to economy in transportation. I speak of this particular case, in view of the fact that it represents ordinary road conditions, not an attempt to obtain maximum economy. There is a great difference whether we coast every grade we come to with the engine shut off, or leave the clutch in from the time we start until we stop. The 30 ton-miles per gal. performance can be and is being obtained in this country on high-acceleration cars, with the clutch engaged from start to stop, the engine throttle being set in the idling position and the accelerator being used during the run. That is very much more expensive in gasoline than under conditions where an attempt is made simply for economy and nothing else. I assume this run was made under absolutely similar conditions. I wanted to call attention to the fact that the economy, while actually high in figures, was not really high, especially for a car with limited comfort available.

T. C. MENGES:—I have operated one of the Petit Peugeot cars for several years. The average performance is about 35 miles per gal. on the country roads. The car weighs slightly more than 800 lb. and is a two-seater. It is not well adapted to our country roads. We shift gears even on paved streets. I do not think very well of it as a practical driving car.

MR. MANLY:—In connection with tests on tires, what are the figures as to the actual efficiency of the tires? We have, for example, a certain amount of power going into the tire and a certain amount of work delivered by the tire. What is the efficiency, both as a supporting mechanism and as a straight transmitting mechanism? A number of years ago some tests were made at Cornell University on bicycle tires, but I have not seen recent data of that kind in connection with automotive tires.

CHAIRMAN CRANE:—We produced some very interesting results of that kind, with a drum dynamometer. The rear wheels of the car were run on a pair of drums, the engine was operated and the power delivered at the rear wheels was measured. The results showed an extreme loss in the power delivered by the tires. In the case of one car tested under those conditions, it lost the difference between 45 and 36 hp. in the tires alone. That is a very high percentage of loss in power. Of course, that was in the days of fabric tires. We know that cord tires are very much better.

MR. MANLY:—The figures obtained in the bicycle-tire tests were very surprising as to the low efficiency of certain classes of tire. The efficiency seems to be almost exactly in inverse proportion to the thickness of the tire. The racing tires they were using on bicycles at that time were of high efficiency, compared with the double type of shoes on automobiles; and those tires showed very much better results, compared with solid tires. If we could get some recent data, I know of nothing that would be more interesting on this question than the general improvement of the economy of the tire. We talk about efficiency of the bearings and efficiency of various other parts, when, as a matter of fact, we actually are losing more power in the tires than in anything else in the transmission of the engine power to the rear-axle.

A. L. CLAYDEN:—Many tests of tires have been made at Yale University by Professor Lockwood. He read a paper[4] entitled Power Losses in Pneumatic Tires before the Pennsylvania Section about 4 years ago, in which he gave the results of a number of tests. I looked at some of the figures a few weeks ago. They show the tire loss is in the neighborhood of one-third of the total. I understand that Professor Lockwood is now getting data together for presentation to the Society this year, and that he has been making these tests with the idea of showing the effect with different sizes of tire carrying the same load.

MR. MANLY:—As regards efficiency, in connection with the matter of tire-inflation pressure, I think these tests will show that the tire is much more efficient when highly inflated. Cars ride more easily when the tires are soft, but I think there will be a tremendous difference in the efficiency when the tire is highly inflated.

CHAIRMAN CRANE:—That is undoubtedly true, but it is also a matter of the efficiency of the casing. In other words, if a perfectly flexible casing could be produced, I think the tire efficiency would be practically the same, no matter what the inflation pressure inside the casing. The fabric tire casing was not flexible; it protested by overheating and blowing up when we did not keep it pumped up. That is the answer to the question as to where the power is being lost. In fact, the tire becomes hot, which indicates that gasoline is being burned to heat it. The only thing there is to heat the tire is the gasoline we burn in the engine. Unfortunately, this wastes gasoline and also wastes tires.

A MEMBER:—I can confirm the remarks made about Professor Lockwood's tests at Yale University. I have run a test recently in which the tires were operated on a drum. This gives a reflex action to the tire. It probably allows somewhat more power loss than would be normal on a flat surface. The tests we have run show that the power loss in a cord tire is 20 to 30 per cent; in a fabric tire it is somewhat higher than that.

W. E. WILLIAMS:—Mr. Putnam mentioned an idea that I think is worthy of serious consideration by the tire-building industry, namely, building a large tire with a thin wall, thus making the tire act in the place of springs to a large extent. In the past the making of a tire that would stand in service has so occupied the attention of the tire builders that this feature has been overlooked or little considered; but now that the cord tire allows the individual cords to move more or less independently and with a considerable cushion of rubber between, there is a possibility of making tires larger in diameter with thinner walls and for lower inflation pressure.

Regarding the task of shifting gears and the statement that the car driver prefers to drive in high-gear rather than bother to shift gears, a large amount of brain power has been spent on automatic gearshifting devices. The trouble is that when one goes through any sort of volition to shift gears, even simply to operate a small lever or button, that act causes as much trouble in volitional labor as is demanded to shift the gears actually. The solution of the difficulty lies in simplifying the movement of the present system of gearshifting.

J. A. ANGLADA:—Referring to Mr. Putnam's paper and to Mr. Williams' remarks relative to the elimination of springs and the substitution of pneumatic tires to do their work, with a five-passenger car we probably would use a tire of 12-in. cross-section. I saw a truck that was fitted with 12-in. pneumatic tires. One of the rear tires exploded when the truck was going about 15 m.p.h. One side of the rear went down and the truck turned over. I am inclined to believe that if we use tires of that size on passenger cars we might get the same result in the event of a blowout.

GORDON J. WATT:—Is there any definite and detailed

[4]See TRANSACTIONS, vol. 12, part 1, p. 377.

information regarding the French test? It seems to me that the results published in this country do not in any way give proper credit to the American cars. It seems that the French cars had expert handling, and that the American cars had no more than ordinary handling at best and possibly very poor handling. They are doing nothing more to save fuel in Europe at present, at least on the cars in use on the public roads, than is being done in this country. They are getting better mileage, but not better ton-mileage. I think that the publishing of the results of the French tests, without further data, is a bad thing for the American automotive industry and an investigation should be made to see whether those published results conform with the actual conditions of the test. I understand that the French cars have very high compression and everything in the way of special lubrication and the like to make the economy as good as possible.

O. A. MALYCHEVITCH:—The Petit Peugeot is a first-class car in every way. In France there are good cars and bad cars, just as there are good cars and bad cars here. There is a difference between French and American car design. It is the custom in France, even in the big factories, to entrust the design of cars to special designers. There are three or four such designers in Paris. I have worked with one of them. They look through the old list which is published in every language, so they can collect all the necessary data; then they design the car. There are a few cars which give very good performance, because they receive the best of attention. Everything in that line which the automotive industry of France produces comes from the brains of three or four men. After the design is completed, it goes to the factories. We are more interested in good production. There are two or three cars in the United States that are really refined. Your conditions are quite different from European conditions; so you must not be worried about recent reports favoring French cars as against the American car.

CHAIRMAN CRANE:—We have had experience in this country with economy tests. They were dropped a number of years ago, largely because they did not mean anything. I happen to know the condition of a certain car in one of the last of those tests. The rear-axle gear-ratio was 1½ to 1. The tires were special cord racing tires. The car was lubricated throughout with machine oil; not even heavy oil, far less grease. The engine had a specially high compression. There was a specially small carbureter. The car would start to roll at a touch. My only ride in this car consisted of leaving the factory one day and going ½ mile. The car stopped. We investigated and found that the gasoline was shut off. A few drops of gasoline had been left in the float-chamber and this was sufficient to propel the car for that distance. The actual contest was on a circular course and this car ran out of its scheduled supply of gasoline a little more than one-half way around. It had 1 gal. to operate on during the race, and was provided with 2 gal. to get home on. It did not get home but ran out of gasoline and had to be towed in.

H. L. HORNING:—It appears that Americans are just beginning to realize the importance of the friction losses in an engine. These losses establish the mechanical efficiency of the engine. Roughly speaking, it requires as much power to run some engines using heavy oils as it does to run the car along the highway. Thus, 50 per cent of all the power developed is lost. This is a very bad showing. A case which I have in mind is that of a 4½ x 6¼-in. engine having a 398-cu. in. displacement. Considering this engine at 1000 r.p.m., the following facts are important.

Grade of Oil	Pull, lb.	Friction Pull, lb.	Brake Mean Effective Pressure, lb. per sq. in.	Brake-Horsepower	Mechanical Efficiency, per cent
Vacuum Arctic	184	16	92	46	92
Vacuum A	180	20	90	45	90
Vacuum BB	170	30	85	42	85
Vacuum B	160	40	80	40	80

The most effective study can be put on piston design, to reduce the mechanical losses in the engine. The losses due to shearing the oil-film can be considered as about 50 per cent of the total losses, at 1000 r.p.m. An hydraulic pressure of 10,000 lb. per sq. in. is developed in an oil-film which cannot escape the rolling-up action such as occurs between the piston and cylinder wall at high speed. Grooves on or holes in the piston relieve the pressure. Recently I tested an efficient automobile engine which had the following satisfactory characteristics.

Engine Speed, r.p.m.	Mechanical Efficiency, per cent	Fuel Consumption, lb. per hp-hr.	Brake Mean Effective Pressure, lb. per sq. in.
600	92.5	58	72
800	91.0	54	75
1,000	90.5	55	78
1,200	90.0	55	78

With an engine of this type in a car weighing 3000 lb. empty, it is not impossible to make 24 miles per gal., or something over 38 ton-miles per gal. I feel that this is a very creditable performance when compared with the ton-miles per gallon and even miles per gallon of some of the smaller European cars referred to.

O. C. BERRY:—To add to Mr. Horning's remarks about the amount of power required to propel a car on the road as compared to the power used up in engine friction, I would say that I have recently tested a car weighing 3100 lb. including the driver and observer, and having a maximum of 3.1 ft. per sec. per sec. acceleration. It required 3.51 hp. to turn the engine over at a speed of 1000 r.p.m., with the throttle set as it would be set in driving at that speed, while only 2.85 hp. was required to propel the car at the corresponding 20 m.p.h. on a hard level road. These figures are characteristic of our "active" American cars, and help to show why so much better mileage can be obtained when the speed of the engine is reduced at the expense of accelerating power. The results of the recent economy tests in France were an eye-opener to me. A Voisin limousine weighing 5300 lb. made 28.3 miles per American gal. This looks high when compared with the customary performance of our American cars, and goes to show what the possibilities are in the way of improving our fuel economy.

I do not agree that an economy test is of no value. I grant that when some particular carbureter is used and adjusted for a certain car at a given speed to obtain the maximum possible mileage, regardless of performance, the results have little or no value. Before the economy test is started it should be required that the car meet very carefully specified performance tests. Under these conditions the results take on a real value. I would like to see the Society of Automotive Engineers, or some similar organization in this country, back up a series of economy tests occurring once a year. I feel convinced that they would result in a real benefit to the industry.

It appears to me that the matter of fuel economy has received less study than any other one feature of the American car. This is a mistake. We are in danger of a fuel shortage, a time when not all of us can ride for want of a sufficient amount of fuel, and those of us who do ride will pay well for our pleasure. The price of our fuel will tend to follow one of two standards. When the raw material is plentiful and can be had by anybody, the price of the finished product will be the cost of production plus a reasonable profit. As soon as the demand exceeds anything that can be produced from the raw material, the price tends to rise until it represents all that we are willing to pay. The French are paying about $1.90 per American gal. for their fuel. If such prices were demanded in this country it would have a serious effect on the whole automotive industry, and such prices are inevitable in the not distant future unless vigorous steps are taken. Hence the great value of any effort that will result in better economy on the part of our American cars.

The foreign engines do not have incorporated in their design any features resulting in high economy that we do not understand, nor do I feel that the American engineer is one whit less resourceful or well informed than the best in the world. I want to see us make a careful and exhaustive study of all the factors influencing fuel economy and set ourselves the task of exceeding the best results ever obtained by the English, French, German or Italian engineers. We ought also to go one step farther and design our cars so that the average driver can approach ideal results more closely than he can at present.

CHAIRMAN CRANE:—I think that Mr. Berry is right regarding the educational value of economy tests at this time, provided a scientific basis could be arranged for them. There is nothing like trying to get the maximum mileage per gallon of fuel out of a car. I hope the matter will be taken up and an attempt made by the proper authorities to formulate a set of rules for an economy test that will really cover stock cars and also what we might call stock driving. In the old economy test the driver was allowed to do anything he chose, and that resulted in a method of driving which is never used by the public. The cars, equipped as I have described them, will coast readily on a grade of about 2 per cent and keep it up indefinitely. They do this very slowly it is true, at 10 to 12 m.p.h., but with the engine shut off, that gains mileage at a great rate.

Our company started some years ago to put speedometers just back of the transmission. After watching this practice very closely for a long time, I do not agree that there is any serious discrepancy between the mileage run by the rear wheels and the front wheels, in ordinary service. That was indicated by tests made at the Brooklands race track in England; the difference was remarkably slight, and I imagine that this track was not particularly smooth in those days. The relatively short intervals of time between bumps on the road are not sufficient to make any noticeable change in the angular velocity of the driving-wheels.

E. W. WEAVER:—If the engine is kept running wide-open at a speed to develop the power that is actually required, we will get the greatest economy that it is possible to get. For instance, if it requires 2½ hp. to run the engine, if we could run it slowly enough so that 2½ hp. is all the power it actually develops, we would get a much greater economy. A series of tests shows that very plainly. That would be equivalent also to having gear-ratios that will allow this in the end.

CHAIRMAN CRANE:—There is no question that this is an absolute fact with the Otto-cycle engine. The more slowly it runs, the less the mechanical loss is; the higher we keep the compression, the better the thermal efficiency is. So, there is every reason to run the engine as slowly as is possible to develop a certain power. The only limitation to this is based on the ordinary design of engine that will not run below 100 r.p.m. and give any satisfaction at full load.

W. C. DAVIDS:—In regard to the transmission and the shifting of the gears, that requires so much strength and acrobatic action, would not the hydraulic transmission eliminate this?

MR. WILLIAMS:—The hydraulic transmission was made successfully over 20 years ago, originating in Minneapolis. It was tested in New York City and showed a power loss of only 15 per cent. They undertook to use it commercially in automotive vehicles, but it would heat up. Not only that, but any bit of sand or grit in the oil would be forced around with the oil through the passage-ways and cut them out. They did use that transmission to get any variation of speed and adjustment in lining up the guns on the United States battleships. There is one vital failure attendant upon the hydraulic transmission. You must still shift something for speed changes and must still control the engine. It is simply a change in gearbox arrangement.

MR. MANLY:—I have spent about 20 years and much money on hydraulic transmissions. They are being used today in turning the guns on American battleships and are very useful and effective. I have also built some for use on large motor trucks, for moving draw-bridges and other work of that kind. In regard to the heating effects, that is a difficulty which must be taken care of, but it can be overcome. As the temperature rises, the viscosity of the fluid must decrease. We have not found any fluid that does not have that characteristic but, on the other hand, the hydraulic transmission is not in the same category as the friction transmission. In connection with the matter of increasing the torque as the speed decreases, we can give an exact increase of torque, with a decrease in the speed, up to any predetermined point. It is merely a matter of design. Something will be accomplished in connection with hydraulic transmission, especially for heavy work.

In regard to the light passenger-car, during the past 20 years I have been attempting to apply the hydraulic transmission but have found that it is not necessary with it. However, in regard to heavy work such as is required of trucks, tractors, road rollers and the like, I think the hydraulic transmission has a very large field. I presented a paper[8] before the American Society of Mechanical Engineers, in 1911, and one before the Automobile Club of America in 1912, which give rather interesting data in connection with this subject. The fault that Mr. Williams criticized in connection with the design he looked at can be overcome.

MR. WOLF:—Referring to Mr. Williams' question about the pump wearing out, I would say that in the particular system mentioned the pistons force the oil out as they come toward the center. Each piston-head was cupped and all foreign matter and sediment would collect in the cup, due to centrifugal force. It was found that this in

[8] See *Transactions of the American Society of Mechanical Engineers*, vol. 33, p. 851.

no way impaired the working of the system. In fact, when dismantled after two or three years of service, all parts were found in good order. The cylinders and pistons were free from scoring. The piston-heads held considerable grit.

It is probable that chassis weight can be reduced still further by more extensive use of alloy steels. Due to its superior characteristics under proper heat-treatment, molybdenum steel is likely to receive the attention of those who are anxious to eliminate excess weight. It seems to me that in frame construction, for instance, effort in this direction will equal or surpass any result that might be obtained by the use of plywood, and at the same time make a far better manufacturing proposition. Rather than resort to extreme means, of which I consider plywood one, I think it would be better to expend the same energy in refining what we already possess.

With reference to the churning of the grease in the transmission, I believe that we should design the transmissions with a small circulating pump so that it can handle light oil and deliver it to the face of the gears. Many years ago the De Dion car introduced such an arrangement and it is now used in a number of tractors. The same recommendation applies to the rear axle, where an oil-pump can be added, or the two applications can be worked together. The pumping loss will be far less than the drag of the grease, especially when the grease is cold.

It was stated that when a wheel goes over a rough road, the wheel would not accelerate due to its inertia. This flywheel effect undoubtedly is considerable, but another thing to be considered is the action of the differential. The conventional differential is too efficient, although it sounds paradoxical to condemn efficiency. When one wheel leaves the ground, the engine tends to speed it up through the differential; this has been observed in high-speed motion pictures that have been slowed down. In one particular case a truck rode over an obstacle probably 5 in. high and, when the one wheel left the ground, one could easily see it accelerate. If this happens with the truck wheel having so much greater mass, it must occur in the case of the lighter passenger-car wheel, and I believe that energy is wasted and tire wear increased by this action. It would be better if differentials did not function when the vehicle is traveling straight ahead, but only when making turns.

I believe that a constant-speed engine with a widely variable transmission system would not result in the engine being used continually at a constant speed. Other systems have indicated this. What we desire most in this combination is the variable transmission ratio, rather than the strictly constant engine speed. In this way we could approximate more closely the desirable results stated by Mr. Nelson in his paper on the Fuel Problem in Relation to Engineering Viewpoint.[6] A great portion of the time that a car is on the road, the engine can easily handle the load on a higher gear-ratio; and, if a practical widely variable transmission were available, it would go far toward solving the fuel problem by working the engine nearer its point of maximum efficiency. For the variable conditions encountered on the road, the present limited gear-ratios are not variable enough to obtain the best efficiency of the engines.

In regard to changing gears, which is a thing that the American driver does not like to do, I believe that if we could have silent operation this would help toward making the public willing to do more gearshifting. There is undoubtedly considerable embarrassment to the ordinary driver who does not wish his friends to know that he must negotiate a grade in one of the lower gears. The noise also produces a mental strain on the driver. Both these conditions could be largely overcome if the gearshifting action were quiet a considerably larger portion of the time. I believe that steps other than those that already have been attempted along this line could be taken to decrease the noise considerably, although it could not be overcome entirely.

FUEL RESEARCH DEVELOPMENTS

BY C. F. KETTERING

THE author first refers to the remarkable progress in fuel research work during the past year and then states that there is a "dead-line" in the utilization of fuel in internal-combustion engines beyond which progress cannot be made. The automotive industry must cooperate with the oil industry and find out what and where this dead-line is; it must know the end-point of fuels obtainable five years hence.

The two distinct divisions of the fuel problem are the fuel distribution in multi-cylinder engines and the chemical changes that occur inside an engine cylinder during combustion. Considering and explaining an elementary case, that of the combustion of hydrogen and oxygen, the components of combustion energy are stated to be gravitational, kinetic and barometric, and these, in turn, are considered and analyzed in considerable detail, with the aid of charts, formulas and diagrams illustrative of molecular structure. Other charts show the normal combustion of propane, its abnormal combustion such as occurs during knocking and the method of calculating the knocking value of an internal-combustion engine fuel.

In Mr. Kettering's opinion, regarding any theory, the greatest difficulty is to obtain a proper conception of the terms employed in its development and to apply this knowledge correctly. This idea is amplified and the strange fact that substances of apparently diverse composition are in reality made up of the same chemical constituents is illustrated by statements regarding several such substances that have been chemically analyzed. That engineers must think of heat in terms of molecular velocity is emphasized and it is stated that the proper fuel mixture for an internal-combustion engine is not dependent upon the molecular construction of the fuel.

Engine friction is one of the most difficult problems with which an engineer must deal and it must be reduced in some manner. The present need is to burn less fuel per car-mile. Numerous charts of indicator cards obtained when using the different available fuels in an internal-combustion engine are exhibited and the different characteristics of the performance of each fuel explained. [To be printed in an early issue of THE JOURNAL]

[6]See THE JOURNAL, February, 1921, p. 101.

VOLATILITY OF INTERNAL-COMBUSTION ENGINE GASOLINE

BY FRANK A. HOWARD

AFTER stating that the meaning of the term "gasoline" seems to be generally misunderstood for the reason that it has been assumed that gasoline is, or ought to be, the name of a specific product, the author states that it is not and never has been a specific product and that although gasoline has a definite and generic meaning in the oil trade it has no specific meaning whatever. It means merely a light distillate from crude petroleum. Its degree of lightness, from what petroleum it is distilled and how it is distilled or refined are unspecified.

Specifically, "gasoline" is the particular grade of gasoline which at a given moment is distributed in bulk at retail. It can be defined with reasonable precision as being the cheapest petroleum product acceptable for universal use as a fuel in the prevailing type of internal-combustion engine. The author places emphasis on the three factors of this definition: (*a*) the cheapest product, (*b*) its universal use and (*c*) the prevailing type of internal-combustion engine.

The author's purpose in this paper is to clear away some of the haze which surrounds the word "gasoline" and with regard to what volatility is with reference to engine gasoline to show how much of the difficulty is inherent in the fuel and how much of it arises from the failure of automotive engineers, collectively, to attain a high average of perfection in the handling of the fuel to develop power.

Ordinary engine gasoline of the grade now sold possesses sufficient inherent volatility to take and maintain the condition of a gas at a temperature at or below average intake-manifold temperatures. Manifold condensation seldom, if ever, occurs and cylinder condensation is even less probable. The phenomena answering to these names are in fact mainly the visual evidences of the failure of the vaporizing device to function. Fuel once vaporized must stay in that condition; hence, if liquid is found beyond the vaporizer, it reached there as a liquid.

These conclusions are based on an examination of the fuel itself. The volumetric proportions of a combustible mixture are considered in detail in the paper and the physical meaning and measurement of volatility are fully discussed, tables of vapor tensions being given and the special apparatus developed to determine the vapor tension of gasoline being exhibited and described. Following this a full discussion of the requirements for full utilization of inherent volatility is presented, the conclusion reached being that the problem resolves itself into the further development, improvement and wider use of the hot-spot. [Printed in the February, 1921, issue of THE JOURNAL]

THE NATURE OF FLAME MOVEMENT IN A CLOSED CYLINDER

BY C. A. WOODBURY, H. A. LEWIS AND A. T. CANBY

THE nature of flame propagation in an automobile engine cylinder has, for some time, been the subject of much discussion and speculation. However, very little experimental work has been done on flame movement in closed cylinders with a view to applying the knowledge directly to the internal-combustion engine.

It has become recognized that knocking is one great difficulty which attends the use of the higher-boiling paraffin hydrocarbons, such as kerosene, and that knocking is one of the major difficulties to be overcome in designing higher compression and hence more efficient engines. It was desirable, therefore, to determine, if possible, the nature and cause of the so-called fuel knock in an internal-combustion engine.

The work described in this paper was undertaken to determine the characteristic flame movement of these various fuels and the physical and chemical properties which influence this flame propagation. The scope of the work is specified and the arrangement of the apparatus for measuring flame propagation is illustrated and described. Flame movement at normal temperature and pressure was then investigated, the results obtained are shown in charts and a table and these are commented upon in detail. The influences of turbulence and of temperature and pressure on flame propagation are treated in like manner, followed by a lengthy discussion of autoignition and the nature of fuel knock, which also is illustrated. [Printed in the March, 1921, issue of THE JOURNAL]

AIR-TEMPERATURE REGULATION EFFECTS ON FUEL ECONOMY

BY REUBEN E. FIELDER

TWO serious problems confront the automotive industry in connection with the present fuel shortage, the securing of a much higher degree of fuel economy with existing equipment and the matter of future designs. These problems are of nearly equal importance.

Because its fuel bill constitutes the second greatest item of expense for the Fifth Avenue Coach Co., operating in New York City, it is constantly experimenting with devices of various kinds to improve fuel economy. Of the different devices that it has tested, the thermostatic temperature-control for the carbureter appears to afford greatest possibilities of saving, and the author presents the results of tests of this device in actual service on motor vehicles.

The thermostat is shown and described and comparative tests made with and without this thermostatic-control device, using the same engine, carbureter and similar equipment, under the same atmospheric conditions, are discussed and analyzed with the aid of tabulated data and charts. The matters of temperature

variation and the volatility of fuel are treated in a similar manner, consideration then being given to what the desired manifold temperature is. Volumetric efficiency is discussed in some detail.

The paper was presented with the primary idea of bringing out constructive criticism. The company believes that the principle of thermostatic control is correct, but that its detailed application is still a matter for further experiment. That there are certain periods during the year when the average internal-combustion engine functions with the minimum amount of trouble is scarcely open to argument. This is because at that time the atmospheric temperature is right. The company's idea is to select this period and standardize it for use throughout the remainder of the year. [Printed in the February, 1921, issue of THE JOURNAL]

FUEL PROBLEM IN RELATION TO ENGINEERING VIEWPOINT

BY A. L. NELSON

THE author states preliminarily that it is believed that never before in the history of the Society of Automotive Engineers has a single problem been so universally studied as the fuel problem that is confronting the industry today. It is also believed that never before has the industry had a problem which includes such a wide scope of work. The solution calls for the service of every class of engineer, inventor and scientist.

The paper does not attempt to give highly scientific information; its real purpose is to appeal for a broader viewpoint and give illustrations and tests which show that the solution of a problem may lie in an entirely different method than that which often becomes stereotyped by sheer usage, rather than by its specific merit. In the solution of the fuel problem we undoubtedly will have to change some of our old habits, replacing them by studiously worked out viewpoints. The further object of the paper is to seek the correlation of the experience of the entire engineering fraternity, to obtain the comments of its members and receive any suggestions they may offer.

After giving recognition to the cooperation and assistance already received and making general comments upon the desirability of radical changes in viewpoint, the author enters upon a discussion of the engine power required to drive a car at constant speed and the effect of using higher piston compression ratios, illustrated by a table and chart, with a view to demonstrating the value of modified viewpoint. In like manner he discusses the constant-clearance aluminum piston and the fuel vaporizer. The basic principles of the engine used in testing are next considered and copiously illustrated, together with the apparatus used in the dynamometer and practical driving tests that were made. Charts show the percentage comparison of results and these are explained.

After a discussion of ideal economy, it is stated that the tests show that an absurd waste is rampant in the present method of applying the indicated engine power and that this subject should be studied from every angle. A close study from the brake-horsepower standpoint may justify changing both transmission and rear-axle drive ratios. The latter combinations, together with engine developments, look the most promising at present. The progress we make will be measured by the extent to which we expand our engineering viewpoint. [Printed in the February, 1921, issue of THE JOURNAL]

RESUME OF BUREAU OF STANDARDS FUEL STUDY

BY H. C. DICKINSON

THE author states that considerable thought has been devoted recently to the relation of fuel end-point to fuel economy. It has been shown that, provided an intimate mixture of fuel-vapor and air is secured, such a mixture will not condense at the ordinary temperatures of the intake. However, on the contrary, crankcase dilution, an excess of deposited carbon, low mileage per gallon of fuel and ignition trouble are being experienced. There appears to be a discrepancy between the efficiency that should be attained and what is actually attained. To investigate this the Bureau of Standards undertook a brief series of experiments to rough out a line of procedure.

Regarding compression of a dry mixture, curves are shown to illustrate that gasoline vapor compresses when "dry." Detonation was evident when using one spark-plug and there was no detonation when using two spark-plugs. After preliminary experiments of the nature already indicated, a pressure indicator was used, at pressures just on the verge of detonation, to find the exact point where detonation occurs. Charts are exhibited to show the location of the piston with reference to its center position, with one spark-plug and with two spark-plugs; and the effect of spark advance on the maximum explosion pressure and brake-horsepower, using one spark-plug. An explanation which goes into considerable detail supplements the charts. [Printed in this issue of THE JOURNAL]

AUTOMOBILE EXHAUST GASES AND VEHICULAR-TUNNEL VENTILATION

BY A. C. FIELDNER, A. A. STRAUB AND G. W. JONES

THE data given in this paper were obtained from an investigation by the Bureau of Mines in cooperation with the New York and New Jersey State Bridge and Tunnel Commissioners to determine the average amount and composition of the exhaust gases from motor vehicles under operating conditions similar to those that will prevail in the Hudson River Vehicular Tunnel. A comprehensive set of road tests upon 101 motor vehicles including representative types of passenger cars and trucks was conducted, covering both winter and summer operating conditions.

The cars tested were taken at random from those

offered by private individuals, corporations and automobile dealers, and the tests were made without any change in carbureter or other adjustments. The results can therefore be taken as representative of motor vehicles as they are actually being operated on the streets at the various speeds and on grades that will prevail in the tunnel. The information obtained can be applied also to ventilation problems of other vehicular tunnels and subways.

The vehicles comprised six representative classes, which are stated, and the test conditions and methods are described in detail. The method of computing the results is outlined and the results are stated and analyzed in the text and in tabular form; a photograph and charts are presented.

The average composition of the exhaust gas, the completeness of combustion and the percentage of carbon dioxide are discussed in detail. A concise summary, in nine specific sections, concludes the paper. [Printed in the April, 1921, issue of THE JOURNAL]

THE DISCUSSION

E. A. SPERRY:—There is a possible explanation of the extra heat loss to the jacket at the moment of detonation. Mr. Midgley and Mr. Kettering have always found a deposit of carbon in the cylinder or exhaust caused by detonation. Also, there is seen through the window a brilliant light at the time of detonation. Inasmuch as radiation is as the fourth power of the temperature, it occurred to me that the black-body radiation of the carbon particles present might help to explain the extra loss of heat to the jacket.

THOMAS MIDGLEY, JR.:—That is a reasonable explanation but we have one or two other points to consider. We have studied the spectrum of the light through a window in a cylinder-head and watched the light of combustion from many different fuels. It is true that with kerosene or gasoline the light is very intense during detonation, as compared with a comparatively weak light when there is no detonation; but with benzol as a fuel, it being rich in carbon, the light is just as bright as during detonation, although there is not the heat or pressure that there is during detonation. I suggest as a possible explanation that in knocking, which is a differential burn of the hydrogen that leaves the carbon behind, the carbon is actually in a gaseous condition following this rather active period. If a piece of steel is put into a steam bath of 212 deg. fahr. and another piece is put into hot air at 212 deg. fahr., the piece that is in the steam bath will heat up more quickly than the one that is in the hot air. If we have gaseous carbon in a detonating explosion, it is certain to produce heat more quickly than simply some hot solid particles.

We encountered a condition in which we had a definite green-band spectrum with the spectroscope during knocking. My colleague said that this showed carbon. We hope to have some definite information about this spectrum ready for the Summer Meeting.

FRED WEINBERG:—I do not believe in Mr. Midgley's theory. We have been unable to gasify carbon; it has never been done. We were, however, able to melt carbon, two years ago. The condition under which carbon melted was the extreme high temperature of the electric arc, in a vacuum. Under ordinary atmospheric conditions carbon will not melt.

L. M. WOOLSON:—I think we must acknowledge that Mr. Nelson's paper is one of the most complete ever read on the subject and that he should be complimented for the very full presentation of data which less broad-minded members might consider confidential and in the nature of trade secrets. I am inclined to take issue with Mr. Nelson with regard to his theory that we need a change of viewpoint. What we actually need is closer concentration on our detail problems. We have been spending most of our time in developing engines for next year's market, adding accessories from time to time. These have included electric starting and lighting, or even electric gearshifts. We have tried all kinds of valve arrangement and drive, starting out perhaps with an L-head engine, testing every other conceivable arrangement and then probably finishing up with an L-head design. Now that these matters are all settled, we have some time available for meeting the problems presented by the cars that are now in service. Most of us are trying to increase the gasoline mileage of our cars; there is, of course, the bogey of gasoline shortage to urge us on in our work of conserving fuel. The advertising departments of various motor-car builders have done some splendid work in securing high gasoline-mileage, on paper. Mr. Nelson has done better, showing that we can secure nearly 50 miles per gal., if we use rear-axle ratios that will rob the car of most of its performance on high-gear, and high-compression engines which will knock badly with ordinary fuel. Nevertheless, I would not accuse Mr. Nelson of being visionary; he ought to be congratulated on setting up a target for us to shoot at, even though we need long-range guns to hit it.

There is one rather important point in the matter of fuel saving that Mr. Nelson has not touched upon and warrants most thorough investigation. In the test shown in Fig. 23 of his paper he gives a fuel consumption of 1.125 lb. per b.hp-hr. at 1000 r.p.m. of the engine, which represents average driving conditions. It is perfectly possible to reduce this consumption to about 0.93 lb. per b.hp-hr., representing a gain of something like 20 per cent in gasoline mileage. All we have to do to obtain this additional mileage is to construct carbureters that will give a lean mixture under average driving conditions, and this can be done without hurting the acceleration or wide-open pulling. Most carbureters are designed to give practically a constant air-gas ratio throughout the range, although experience has shown that this is not required in actual operation. While this possible 20-per cent saving is small in comparison with some of the savings pointed out by Mr. Nelson, it is within our reach without any accompanying disadvantages.

Mr. Nelson does not offer any conclusive evidence that sufficient heat is furnished to the mixture under average driving conditions. The ability to accelerate well in cold weather without pulling the choker soon after staring certainly does not prove the point. That depends on how rich a mixture the carbureter was set to furnish at the time. Although I have been for some time in favor of rather higher intake-mixture temperatures than are usual, it is only recently that I have found that still higher temperatures are desirable from the standpoint of maximum economy and maximum performance in acceleration. I believe that we should refer to actual intake-mixture temperatures when we discuss methods of fuel vaporization, instead of to car performance in a general way or to other less specific data. There is no question that there is a certain desirable range of mixture temperatures that will probably apply to all engines under the same conditions, and I believe we ought to know what that range is. The Bureau of Standards has shown that greatly improved acceleration can be obtained by raising the mixture temperature, but I believe it has not inves-

tigated or at least reported the great gains in economy possible under ordinary driving conditions with mixtures at rather high temperature, given, of course, suitable carbureter adjustment. I venture to say that the desirable temperatures will be found to be about 100 deg. fahr. above those obtaining in the average intake-manifold.

It appears that there will be considerable variation in opinion as to the significance of actual manifold-temperature measurements. As pointed out by Mr. Howard, it is not desirable to heat the air unduly, but it is necessary to apply fairly high temperatures to the fuel. In one case we may have an average mixture-temperature of 120 deg. fahr. and a relatively poor degree of vaporization, and in another case with the same average temperature almost complete vaporization. Nevertheless, we must determine the best average mixture-temperatures under different conditions, and Mr. Horning's suggestion that these be determined in terms of carbureter efficiency is a real constructive step. This work is to be undertaken by the Bureau of Standards and the Bureau of Mines in the immediate future, if the necessary funds can be secured.

Mr. Nelson made some rather positive statements regarding the value of certain types of aluminum piston, which I believe should be accepted with reservations. It is only after we have had a great amount of operating experience under average driving conditions that we can be sure of our ground in a case such as this.

A. L. NELSON:—I am glad that Mr. Woolson is inclined to take issue with me relative to a change in engineering viewpoint. I believe we have been doing for years what Mr. Woolson suggests; nevertheless, we have perhaps paid too close attention to mere details and our feet are not yet touching the ground when it comes to the fundamentals underlying our problems. Mr. Woolson gives a rather unique picture of the development of a certain new engine which started out with an airplane birth, so to speak, and wound up in a rather conventional L-head type, the type that has been in use for years, particularly in low and medium-priced cars. It is hard to understand why the engine referred to has any bearing on the matter of valve arrangement, as Mr. Woolson infers.

Mr. Woolson apparently believes that almost all advertising departments are proverbial liars on gasoline mileage. He says that I show still better results, namely 50 miles per gal., but at a sacrifice of good performance. There is not one fair-minded capable engineer who will not agree with me relative to the ideal mileage possible as shown in Fig. 33 of my paper, under the conditions set forth. Furthermore, we do not have to use engines that knock badly. If Mr. Woolson had looked more carefully into my paper, he would have found increases in economies over twice as great as what he cites as possible at ordinary driving speed. In the test shown in Fig. 23 of my paper, we get 1.125 lb. of gasoline per b.hp-hr. at 28.6 m.p.h. Mr. Woolson places stress on this figure and contends that by proper carburetion it is possible to make this 0.93 lb. per b.-hp-hr., representing a gain of 20 per cent. However, I also show, in Fig. 27, results slightly better than 0.93 lb. per b.hp-hr., and in Fig. 26 at this same car speed we get 0.75 lb. per b.hp-hr. This is a 24-per cent increase in gasoline mileage over what Mr. Woolson claims proper carburetion will give. For the cases cited above, the carbureter had relatively very little to do with the results obtained. I will mention a little later the results obtained so far as the carbureter is concerned.

I am sorry that Mr. Woolson looked for conclusive evidence in my paper with regard to whether the proper amount of heat was furnished under average driving conditions. He should read the second paragraph of my paper more carefully. The result of the tests shown in Fig. 28 indicate that the vaporization at partial loads was not really bad at least; also, the indicated thermal efficiencies of the tests in Figs. 26 and 27 are not bad. Mr. Horning points out that the results come within his expectations, after a study covering fundamentals which were not treated in my paper. The results, although not perfect, are found to be fairly good. To go into the details of making the results possible is beyond the scope of my paper. As to whether the mixture was over-rich when accelerating with the engine cold, the mixture used for this open-throttle condition was one which gave a gasoline consumption of less than 0.52 lb. per b.hp-hr. Comparing this with the results of our best aviation engines, which do not carry fan and battery-charging loads, it appears that an over-rich mixture was not used in tests without an accelerating pump. Mr. Woolson admits that he found recently that higher temperatures give better results. He will find that there is still further room for improvement, and also that there are new devices which have considerable merit.

Mr. Woolson pleads for the acceptance of my statements regarding the aluminum piston, with reservations. During the war I was in the gun business for the Government. We learned that we could accomplish what we went after. It required hard work, but I think we demonstrated to all our Allies that we could shoot more accurately than they could when it came to mixing bullets and propeller blades. In view of those records, I will trust to having the statements I made relative to the aluminum piston accepted without any reservations whatsoever until the results claimed can be verified by personal observation.

There is one matter in connection with these tests in regard to which I do not wish to be misunderstood. A case in point is Mr. Woolson's remarks relative to the improvements that can be made in performance at a few fixed car speeds and concerning additional tests that are desirable to make the investigation more complete. The latter had to be omitted from the paper for brevity's sake; also, the time for conducting the tests was very limited. The first test was run on Dec. 18, 1920, and the last one on Dec. 28. The results show clearly what can be done with one carbureter setting over a range of speeds from 10 to 60 m.p.h. and at wide-open throttle for speeds from 400 to 3200 r.p.m. The results that it is possible to attain under ordinary limits and with diligent care are far in advance of those given in the paper. The thing to remember is the wide range of conditions that were met with one carbureter setting. The ultra results at a few speeds are comparatively easy to obtain.

C. P. GRIMES:—I think that Mr. Nelson should be complimented upon the way he has presented his paper, inasmuch as he has approached the subject from a definite viewpoint. About the time the war started, Mr. Nelson investigated guns and was able to develop a cam, used in the Nelson gun control, which excelled any developed by those who had spent years in the gun business. Sometimes we work in one line and do not go far enough afield to get a real perspective of what we are trying to do.

I am most interested in the general car performance. Mr. Nelson has shown in his paper that we are using a power factor of 15 per cent; I mean that the power used is only about 15 per cent of the available power. Under

ordinary conditions of 20 to 30 m.p.h., car owners would soon go broke. We have all been using gasoline with the power factor not to exceed that. I made some tests on the road in which I obtained some rather interesting data. We ran at 20 m.p.h. over a level road at 10, 20, 30 and 40-deg. spark-advance. I found that every time I advanced the spark I obtained a few more miles per gallon. In general, the automatic spark-advance is fairly common. We can set that at the full-power condition. I think that shortly someone will arrange to have the spark at partial-throttle conditions advanced to that point which gives the best result in miles per gallon of fuel.

There is another method of obtaining the horsepower which really is required to drive an automobile on the road and which is available to that automobile. The system of adjusting the throttle-valve that Mr. Nelson used on the race-track at Indianapolis is very good. However, he said nothing about where he carried the spark. It is to be presumed that he exercised the same care in the location of the spark as in the location of the throttle. That would require, of course, a spark protractor on the automobile. This is simple to apply. Take the starting-crank off and replace it with a disc of tin; then turn a wooden plug to fit the inside of the starting-crank hole, so that it projects somewhat, and put a steel pointer on it. Set cylinder No. 1 on a dead-center position. After marking off a few degrees on each side, take a file-handle and a piece of flexible cable and run the wire from the cylinder around this round handle and touch the center with the pointer. The man who drives the car can set the speedometer and watch that little spark jump, wherever it is. If anyone had tried to tell me a short time ago that a 5-deg. difference in the spark-advance makes a difference in the ability of the automobile, in regard to the acceleration, economy or hill-climbing, I would have thought him wrong. Long ago I made tests with spark protractors in which it seemed that there was plus or minus 6 to 8 deg. of spark-advance. I have changed my mind because about 50 tests which I made all seemed to check.

The subject of acceleration was discussed before the Indiana Section of the Society in February, 1916. The method of using a stop-watch and an ordinary speedometer was set forth. The mass of an automobile traveling along a level road has a certain amount of energy; one-half the mass times the square of the speed. If we decrease the speed the car has not so much energy but a certain number of seconds is required to dissipate it. Ordinarily, when we run a car at 3 m.p.h. and the driver accelerates it, we find the best spark for acceleration and snap the stop-watch at 5, 15, 25, 35, 45 and 55 m.p.h. Then we figure out the number of seconds, weigh the car on ordinary scales and get the number of accelerations. I am speaking of these things because I hope to encourage more engineers to find out the exact resistance of the car and its weight, and put it on the dynamometer and continue the research which Mr. Nelson has started. I have made tests for acceleration on a number of different cars. I have been rather surprised to find that weight does not seem to be the main factor at all. We know that 60 per cent of the resistance, at a speed of about 20 m.p.h., is wind resistance; the remainder is bearing friction and top resistance.

In regard to the heat in manifold conditions, I have observed that as long as the air is kept at ordinary temperature, the hotter the hot-spot, the better are the economy and the acceleration.

MR. NELSON:—Mr. Grimes' method of studying car performance is indeed interesting, particularly the method of determining the load factor. This is a quick and ready means of getting approximate results. My experience with speedometers has, however, been very unsatisfactory. The inertia effects of certain parts are so marked in some types of instrument that I would never think of using them to determine car acceleration. When the car acceleration is increasing, the speedometer lags; and when the acceleration is decreasing, the speedometer runs ahead of the true reading. Driving a high-grade car I pulled out the reset while the car was standing. After doing this, the speedometer quickly showed 20 m.p.h. and, of course, soon showed zero again. An instrument which is so sensitive to shock certainly cannot be used in laboratory work. These remarks necessarily do not apply to all types of speedometer, but if care is not used to select the type of instrument most suitable for testing purposes, the results will be very questionable.

In reference to the spark location used in the tests, only one setting was used. The automatic advance took care of the spark location. Our experience has been that, with a proper quality of mixture, the spark-advance is not nearly so important as when the mixture is slightly wrong. In checking the results as mentioned by Mr. Grimes, we have found almost invariably that the quality of the mixture was wrong. This may vary with different engines and Mr. Grimes' suggestion is worthy of careful attention.

HERBERT CHASE:—Mr. Nelson has hit upon a point which few others have emphasized, namely, the necessity of getting better economy under the part-load conditions that obtain in the average passenger-car, particularly, during a very large percentage of the time of operation. Testing is done at full load almost entirely and few engineers give the consideration that they should give to the matter of load factor mentioned by Mr. Grimes.

Mr. Nelson has shown one way in which it is possible to increase the fuel economy at part load, and it is a subject deserving of further consideration. There are other methods of accomplishing the same thing. One is to build a constant-compression engine. I mean an engine of conventional type that is a constant-volume engine, but which has constant compression at all loads. This has been done in England by Mr. Ricardo. Others in this country have experimented with the same thing. I know one engineer who has a six-cylinder car of about average size on the road today, with which he claims to be getting close to 60 miles per gal. Such a performance, if it can be realized commercially, would constitute a long step in advance. The method in this particular case is always to take into the cylinder practically the same amount of air controlling the amount of fuel in proportion to the load demand. The rich mixture that is taken in through one additional valve is, to a certain extent, localized in a portion of the combustion-chamber adjacent to the spark-plug. Then there is always an excess of air under part-load conditions. At wide-open throttle, there is simply enough air to burn the entire charge. That is one way of getting this desirable economy at part load. There are other methods. Variable valve-timing will help. Mr. Sargent has presented papers before the Society in which that has been the theme, but it is a matter that should be given further and more thorough study than it has received to date. We have done much in the way of adding accessories, hot-spots and what not, all of which are commendable and have produced some increase in economy, but we must, if we can, get rid of the basic thing which causes lack of economy, namely, the throttle, which

can never be efficient as long as it continues as a throttling engine.

EDWARD D. THURSTON, JR.:—In connection with Mr. Fielder's work, Fig. 2 of his paper shows the results of a test as to the saving in fuel consumption and increase in horsepower obtained as a result of using the thermostatic control. Also, in Table 1, he presents an economy test which gives the power developed, the fuel consumed and the manifold temperature. The changes are rather small and I ask Mr. Fielder if the ratio of fuel was precisely the same under the two conditions; that is, whether the carbureter was readjusted to have the same ratio of fuel. Very little variation in the carbureter setting or very little change in the mixture would account for a difference of only 0.04 lb. per hp.

In connection with Mr. Howard's paper, he speaks of determining the vapor pressure of gasoline by introducing a certain amount of it into a barometer tube, the increase in pressure being the partial pressure of the gasoline. That seems to me to be perfectly practicable in the case of a simple liquid, or, if a small amount of gasoline is placed in a tube, the pressure will surely rise a certain amount; but I have found by experience that it makes a great difference how much gasoline is put in. If we introduce 2 or 3 cc. of gasoline, we may find a pressure-increase of 2 or 3 in. of mercury; if we put in 5 cc. of gasoline, there may be twice that amount of pressure increase. What is the vapor rating of a gasoline? Is it the first rating or the second? I do not understand yet how we are to get the vapor pressure of gasoline.

In connection with the cooling or the drop of temperature in the inlet manifold, that introduces an interesting point in regard to measuring the temperature in the manifold. This has been brought rather forcefully to my attention in the last few weeks because I have been doing some work along this same line. In some cases at least the apparent temperature drop through the carbureter is greater than could be accounted for by the evaporation of all of the fuel. In other words, if we evaporate the entire pound of fuel, we would have 130 heat units available. The fall in temperature of the air times the specific heat times its weight is greater than 130. Obviously, something is wrong. Mr. Howard's paper has given me a clue to the explanation. The mixture is probably still wet, some of the unvaporized fuel has become lodged upon the temperature-recording device and, by its evaporation, has given us a false reading of the mixture temperature. I cannot see that this will be very different with different types of measuring instrument. Whether we use the thermocouple or the thermometer, the result will be about the same and that rather leads us to suspect that some of the manifold temperatures we are recording are not the average or correct temperatures; that they are too low, on account of vaporizing some fuel on the temperature-recording element.

R. E. FIELDER:—No attempt was made to keep the ratio of fuel to air precisely the same. Conditions, physically, were kept the same as nearly as possible throughout all comparative tests; the magneto timing and the carbureter setting remained the same.

J. D. GILL:—For the past several years, as a refiner and marketer of gasoline, I have heard many complaints about commercial gasoline. For the past three years I have attended the Society meetings, particularly the fuel sessions, in the hope that I might find out just what the automotive engineering profession wants for engine fuel. Perhaps the petroleum refiners could not provide just what is wanted, because immense quantities of engine fuel are being demanded, but the refiners do wish to know at least what is desired and having this information would try to live up to such broad specifications as might be determined.

I have not seen any direct comparisons of different kinds of engine fuel, with respect to either accelerating power or fuel economy. The conclusion I have reached after letting my mind run over the many accessories that have been added to the car to assist carburetion, vaporization and the like, and the many fuel experiments that have been performed, is that, if certain things are done, such as the installing of hot-spots, satisfactory results will be obtained with the present-day commercial grade of gasoline.

Two outstanding factors have been mentioned repeatedly in connection with the burning or utilization of engine fuel. One is that, under certain conditions, knocking ensues; the other is that an undesirable dilution of crankcase oil results from the use of present-day fuels. In Mr. Howard's paper it was shown that, under proper conditions, fuel taken into the system is perfectly volatilized and remains a dry gas. This is the condition that was sought to eliminate the dilution of crankcase oil. The statements made by Mr. Howard were confirmed by the experiments described by Dr. Dickinson, in which the vapor tension of practically all the components of gasoline which he examined was below the corresponding values on the adiabatic curves, showing that the material would remain dry at the ordinary compression pressures in the cylinder.

Keeping these things in mind, but passing to one of the other factors for a moment, we have seen also that knocking results with lean mixtures in the cylinders. In the present-day engine, having a long manifold system, there is no doubt that the distribution of the fuel is not uniform and that different cylinders receive different quantities of the power supply. May it not then be that some of this knocking which we have been talking about is not at all due to the character of the fuel itself, but to the lack of the fuel in proper quantity at some certain cylinder? I repeat that all that has been said indicates that if "certain things" are done, the gasoline that we are using today will give satisfactory results.

However, we can accomplish our purpose most readily by utilizing the physical characteristics of gasoline cited by Mr. Howard. If in a water system that has a reciprocating pumping unit we desire a continuous flow of water, we put into the system somewhere between the pumping cylinder and the delivery point a reservoir, so that the pulsations of the pump are lost in the large volume of the reservoir and the flow of liquid is continuous. That is about what we desire, it seems to me, in an internal-combustion engine. Reverting again to Mr. Howard's statements and their confirmation by Dr. Dickinson, we find that we can make a perfectly dry mixture and that it will stay dry without the application of heat; but time is required for this complete volatilization of the fuel.

Suppose we were to put into the system, somewhere between the carbureter and the place where the fuel mixture enters the cylinder, just such a reservoir in which the "pulsations" from the carbureter would be thoroughly mixed with the air and given time for vaporization. Suppose also that the mixture which finally passed out of this reservoir was in conformity with Mr. Howard's idea of a dry complete mixture of somewhat under 2 per

cent of fuel mixed with air. Would we then have the knocking which comes from poorly fed cylinders in the system, and would we have the excessive crankcase dilution which has been a source of very great annoyance within the last few years?

I feel that perhaps some of the criticism which arises from crankcase dilution may not be justified solely by any increase in dilution that we now experience; we are inquiring much more closely into performance today than we did years ago. Crankcase dilution, of course, always existed, but perhaps we can agree that it has been excessive. Can we not improve conditions by making the mixture complete and dry, not by using the hot-spot or other means which have been placed on the market, but simply by giving the fuel sufficient time in which to vaporize completely and mix with the air before it passes into the cylinders?

PRES. J. G. VINCENT:—We should not overlook the fact that the average car is working much of the time under conditions that are not ideal. The automobile is used to a great extent for business now, and many trips in cold weather are just to the house, the store or the office. In many cases such trips do not occupy more than 10 to 15 min. of time in very cold weather. We ought not to conclude that all these devices perform as well as they should under such circumstances.

F. C. MOCK:—In our organization we are not sure that the volatility of a mixture of a series of elements can be determined by separate measurements of the volatility of each element. Some years ago we seemed to find that when 56 to 58 deg. Baumé Mid-West gasoline was introduced into about 15 times its weight of air at atmospheric pressure, only about 30 per cent of the gasoline would evaporate in an indefinite length of time. A fan circulation was used to avoid local segregation of the vapor. We did not follow through the method described by Mr. Howard of determining by fractional divisions the amount that should evaporate, but I am sure that this method of computation would have shown a much greater percentage of evaporation. I have read that a certain French physicist seemed to find a condition of mutual saturation existing between closely related elements such as these, and this may be the reason for the discrepancy. To present the results of our experiments in more striking form, I would say that they indicated that if an amount of gasoline sufficient to "carburet" the air in the hall in which this meeting is being held were kept in open vessels, or spilled upon the floor, it would be perfectly safe for persons to light matches and smoke, provided open flame was not brought into contact with any liquid gasoline. I have not tried this.

I note that one of Mr. Howard's illustrations is based on a pressure in the engine manifold of 0.5 atmosphere, which would be about 14¼-in. of mercury vacuum. We practically never have any trouble with vaporization at this vacuum and, under nearly all conditions of our observation, the manifold is substantially dry in such a vacuum. Where we have our trouble is at wide-open throttle, when the manifold pressure is nearly a full atmosphere.

One rather remarkable thing is that we apparently find that many engines show just as good power and fuel efficiency with the gasoline feeding to the cylinders as a stream along the walls of the manifold, as when the fuel is converted into a mist with a "hot-spot," under conditions of steady load and air speeds above 60 ft. per sec. *Cold manifolds fail under changes of speed and load*, and at temporary periods of driving where the air velocity falls below the limit already mentioned. We do find considerably less carbon deposit when the fuel goes to the cylinders in the form of a mist.

GEORGE M. BROWN:—So far as Mr. Howard's paper concerns the evaporation of fuel, I believe that it is very nearly correct. This opinion is based on more than seven years of experimental work in the interest of fuel efficiency. This time was spent entirely on the road, in traveling close to 100,000 miles under all conditions. I note no very appreciable difference in the evaporation possibilities of fuel today from that of 10 years ago, under my principles of usage.

Mr. Howard gives an equation representing evaporation in terms of time, surface and heat. To this he should have added what I might call "dispersion." Elementary physics teaches us that this is the effect of wind on evaporation, insuring an equalization of the vapor content per cubic inch of air, or an equal degree of saturation. My experiments have been based on the primary principle of a very large surface and very rapid dispersion which produces an effective evaporation and thoroughly equalized mixtures. This condition is attained through the carbureter instead of the manifold, thus insuring a mixture of equal richness in each cylinder, and depending simply on manifold design against wire-drawing in any particular cylinder, to prevent an inequality in volume.

From my long experience I believe that the solution of the fuel problem is based on surface and dispersion at initial contact, which is turbulence in the carbureter. My practical tests have proved that every possible benefit can accrue from this condition, as to both fuel economy and engine efficiency, with the minimum of complications.

In his answer to the fuel questionnaire, Mr. Horning states that he is studying turbulence as the most effective factor. After a close study of the application of turbulence in both ways, I do not know that it makes a great difference whether we start or end with this idea; but to start with it gets results by a simpler method and I believe that this reduces distribution difficulties. The two reports from Mr. Howard and Mr. Horning appear to be of marked value from a practical standpoint.

FRANK A. HOWARD:—In regard to the questions that were asked on the vapor tension of gasoline, it is quite true that the more gasoline there is the higher the vapor tension will be, within limits. The method by which that is met is to take the maximum vapor tension which can be obtained with a sample of adequate size and continue to add gasoline so long as the pressure shows any increase. In the case of the original gasoline, that is a very difficult matter because there is a small quantity of dissolved permanent gas in it. I suppose, if enough gasoline were added, the pressure could run up to equal that of the atmosphere. That criticism does not apply to vapor-tension determinations or distillation residues. That last 10 per cent can be regarded as a very nearly homogeneous compound. There is another way of checking it which is very good. The chemically pure hydrocarbons in the gasoline can be isolated and vapor-temperature determinations made on them.

As to the measurement of manifold temperatures, that wet-bulb thermometer effect is bothering many engineers. In my reference to manifold temperature I was talking about a dry mixture. I have no idea how to obtain a true indication on a wet mixture.

I said I did not know of any way of increasing the time element for vaporization. Mr. Nelson has already found a way for increasing it. This shows what the

progress in respect to hot-spot design is and what is possible in the way of juggling the three factors of surface, time and heat. Apparently we can handle all three of them now. None of them is excluded.

Mr. Brown raises the point that, in addition to the factors of time, surface and heat, the element of "dispersion" enters into volatilization. This is correct in the sense that the dispersion of the fuel vapors in the air must be great enough to give substantially a homogeneous mixture if the full inherent volatility of the fuel is to be utilized. It is theoretically possible that stratification or lack of homogeneity either in the intake pipe or in the engine cylinder might give the condition of a saturated stratum of air into which the fuel could no longer vaporize, and above this an unsaturated stratum. While the average volumetric content of fuel vapors in the charge would, therefore, be below the partial pressure of the fuel at that temperature, vaporization would be arrested until the process of diffusion equalized matters. True gaseous diffusion is, in itself, probably much too slow a process to be of value in carburetion and, while this is theoretically covered by the time element, turbulence therefore enters as a necessary practical factor for the utilization of full inherent volatility. This is not, of course, limited to cylinder turbulence, but includes turbulence in the carbureter and manifold as well.

President Vincent has directed our attention to the fact that the starting or warming-up problem is a very serious one which is often overlooked in discussions of the vaporization of fuel. There are many promising mechanical solutions of this trouble and I have no doubt these will be developed to meet perfectly the requirements for engines to be built in the future. With regard to existing engines, however, very little seems to have been done to help out on this matter. We have attacked it from the fuel standpoint by marketing at retail, with such wide distribution that we hope practically all motorists will be reached, a special high-volatility fuel which can be called a petroleum ether. The value of such a product for priming is, of course, well recognized. This particular product is so highly volatile that it readily forms an explosive mixture at a temperature as low as 72 deg. fahr. below zero, which is as low a temperature as we have been able to obtain in our own laboratories. There is being marketed with this priming ether a priming-cup, which can be mounted on the dash. This cup is in reality an elementary carbureter, having an air passage into which the priming ether is sprayed from a calibrated jet orifice. The capacity of the cup is sufficient to run an ordinary engine for about 35 sec. The device is operated as follows. The engine is started and run for about 500 revolutions on a fuel so volatile that low air and engine temperatures have no effect. This running period is long enough to warm the engine up fairly well. Of course, the better the hot-spot or heating device is, the more perfectly normal intake-pipe conditions will be established within this time. It is found in practice that this device can be operated without any particular skill. The regular throttle-valve is merely set in the idling position, the priming-cup filled and the engine started in the ordinary way, the choker-valve being wide-open. The richness of the mixture supplied by the primer is such that the dilution with air through the crack in the throttle-valve does not reduce it below firing proportions. Before the cup is exhausted, the engine will usually be warm enough so that the throttle can be opened fairly wide and the regular carbureter will come into operation without the use of the choker-valve. Here again the leakage of air through the priming device is so small, with the throttle appreciably open, that the regular mixture of the carbureter is not reduced below explosive proportions. The primer, therefore, need not be shut off at the exact moment when its charge is exhausted, but should, of course, be shut off before the throttle is closed again.

This method of meeting the difficulty which President Vincent mentions has obvious disadvantages, but it does seem to afford a cheap and simple means for the ordinary motorist to obviate winter-starting and warming-up troubles.

A. C. FIELDNER:—It is truly astonishing that more attention is not paid to the composition of automobile exhaust-gases. I believe it would promote gasoline economy if manufacturers would install a gas-sampling connection in the exhaust pipe, between the muffler and the engine, and bring it up to some convenient place on the vehicle where a gas sample could be taken at any time. It certainly would pay large trucking companies to employ a chemist who would analyze the exhaust gas on motor trucks for the purpose of checking up carbureter adjustment.

MR. CHASE:—I have been very much interested in Mr. Fieldner's paper because on behalf of the Society I had something to do with suggesting the nature of the tests described. When the matter was broached several months ago, we placed particular emphasis on the desirability of conducting the tests under the actual conditions of service. I expected that the results would show exactly what they have shown; that the average car today is wasting, due to incomplete combustion, at least 25 per cent of the fuel that is fed through the carbureter. Not only does the engine run under the inherently inefficient condition imposed by throttling, but only 70 per cent of the total fuel fed is burnt. We sometimes criticize, with more or less justice, the oil companies for the quality of fuel that they furnish, but when a condition such as the one that has been shown by this paper to exist is present, it is certainly evident that there is much to be done by the automotive engineers and manufacturers as well as by the fuel producers.

C. A. FRENCH:—In the experiments described acetylene, sulphuric ether and carbon bisulphide were exploded in a closed cylinder of fixed volume. A glass window, running the entire length of the cylinder, was used to permit the making of photographs of the flame as it passed through the cylinder after having been ignited at one end. Such experiments are of great scientific interest and value, and these gentlemen should receive all possible encouragement to continue the work, particularly as combustion research has always been at a low ebb in this country. We should not, however, take these preliminary results as being necessarily indicative of anything that happens in the cylinder of an engine burning kerosene or gasoline, for the reason that the fuels used in the experiments are incapable of burning like paraffin hydrocarbons.

The first prerequisite of an unobjectionable flame for internal-combustion engines is that it be so blue, nonluminous, non-radiant and of such low actinic power, so that it is extremely difficult to photograph in the time interval available. Moreover, all of its characteristics are radically different from those of any luminous flame. In attempts to find the causes of our trouble with kerosene and gasoline, countless experiments in flame propagation, ignition temperatures and the like have been made, but in 99 out of 100 cases other fuels than kerosene

and gasoline have been used, the conditions under which kerosene and gasoline are burned were not stimulated, and the results obtained, while of scientific value, have not helped us materially in our problems.

A comparison of acetylene, sulphuric ether and carbon bisulphide with hydrocarbons of the paraffin series shows a great difference in their structure, compositions and characteristics. The ethanes, of which acetylene is the first member, have an empirical formula $C_n H_{2n-2}$ and all are unstable, unsaturated hydrocarbons. Acetylene gas has about the same weight as air; hence it diffuses slowly. In the formation of unsaturated hydrocarbons some of the carbon atoms, not being able to secure all of the hydrogen they would like to have, are compelled to form double, or sometimes triple, bonds with each other. Carbon atoms are always very reluctant to form these double or triple linkages between each other, it being necessary always to supply energy to force such a union. When these substances burn, they give off more heat than is indicated by the amount of carbon and hydrogen they contain. Such compounds are endothermic, that is, formed with a disappearance of heat, which is given off again when they dissociate. In the case of acetylene, this excess heat is about 23 per cent. Highly endothermic compounds of this kind are always unstable and may dissociate with explosive violence in the entire absence of air, oxygen or any other supporter of combustion. Under that condition, Berthelot and Vielle dissociated acetylene with a resulting pressure of 5638 atmospheres, after which the carbon was left as a solid lump with a brilliant surface. Explosive dissociation of compressed acetylene so frequently occurs spontaneously that all civilized countries prohibit its shipment or storage under pressure of more than 1 atmosphere, unless dissolved in acetone, or other solvent, and the solvent absorbed in a porous solid.

Except when used in special burners, it produces soot with mixtures of any ignitable proportions whether burned explosively or otherwise. The blue-flame period of acetylene burned explosively is extremely short and complete dissociation with more or less violence occurs at an early period, causing a halt in the oxidation, after which the free carbon and free hydrogen may or may not burn, according to circumstances. It is decomposed readily by heat, when it may completely dissociate, or it may polymerize into any one of a vast number of organic compounds. Thus we see that it is a highly endothermic, unstable gas, the flame characteristics of which are, except under most unusual circumstances, very different from those of the paraffin hydrocarbons.

Sulphuric or di-ethyl ether consists of an ethyl radical on each side of an oxygen atom; while the bonds of carbon to oxygen can be said to be fairly strong, nevertheless compounds containing them are often very reactive. Ether vapor allowed to flow through an expanding nozzle into an exhausted tube, 4 to 6 ft. long, turns its kinetic energy into heat on reaching the end of the tube and dissociates with considerable explosive violence. Any of the organic molecules having two similar radicals, bonded between them to an 0, or to a ketonic oxygen CO, are prone to have unusual properties; the vapor tension of ether is characteristic of one of its radicals instead of the whole molecule, showing that the two radicals do not join forces to any considerable extent. This tendency of the radicals to act independently, that is characteristic of the ethers and at least some of the ketones, shows an anomalous bond that should warn us that these substances would, under certain circumstances, dissociate with considerable emphasis. We should expect about the same sort of a ragged pressure line from the explosive combustion of ethers and some of the ketones that we get from the dissociation of the highly endothermic fuels.

The paraffin or saturated series of hydrocarbons have the empirical formula $C_n H_{2n+2}$. Their heat of formation being positive they are not under any stress and are therefore stable. From methane, CH_4, the first member, up to and including pentane, C_5H_{12}, all members of the series could probably be burned explosively under as high compression as we would care to use in automotive engines, and they would never produce detonation or other objectionable effects, unless an excess were used. All periods of their flames would have a transparent blue color. At least it seems certain that neither detonation nor luminous flame could be produced in a homogeneous stoichiometrical mixture of air and paraffin series molecules, no molecules of which contained more than 12 atoms. Such a mixture should burn under any pressure or at any velocity with no undesirable effects. A stable hydrocarbon molecule of not more than 12 atoms has all of its atoms on the outside, or at least in communication with the outside, so that throughout combustion every fuel atom is being bombarded with oxygen molecules and atoms enough to burn them; under such circumstances oxidation will always take precedence over dissociation. There is no experimental evidence to show that detonation or knocking has ever occurred in an entirely blue flame of a paraffin hydrocarbon, or in ring compounds of not more than 12 atoms.

With a molecule as large as hexadecane, $C_{16}H_{34}$, the largest molecule usually found in kerosene, its size prevents more than 37 of its atoms having contact with oxygen; therefore the 13 inside atoms must wait for oxygen until the outer layer is burned away. If this burning takes place too rapidly, the oxygen cannot secure contact with the inside atoms of the fuel molecule until too late to save them from cracking. In all reason we would expect the 13 atoms of C_4H_9 to be the end of the chain. As no such compound can exist, it would crack in the characteristic manner of the saturated series into one saturated and one unsaturated compound, which in this case would be ethane, C_2H_6, and acetylene, C_2H_2, and one lone hydrogen atom.

We should expect this kind of a combustion to halt when the 37 outside atoms were burned. The cracking and the formation of the acetylene would absorb some heat, and the acetylene would then dissociate with explosive violence; after this the free carbon, free hydrogen and the ethane would burn, making two and possibly three pressure peaks on the diagram. The flame begins blue, *as do the flames of all hydrocarbons*, and stays blue until the 37 atoms are burned away, after which it becomes brightly luminous, radiant and actinic. Practically always, an excess of fuel is followed by dissociation, even with small fuel molecules. A dissociation is always productive of the mixture. While a reasonable amount of ionization is necessary and desirable in combustion, an excessive amount can and does produce effects that are most undesirable. A luminous flame always denotes excessive dissociation.

It is important to remember that any kind of a flame of a common liquid hydrocarbon fuel cannot be propagated without an initial area or period of transparent blue flame in which the fuel and air are in explosive proportions. Entirely green, lavender, red, yellow or white flames cannot be propagated, nor can they be maintained if too widely separated from the blue flame. If a yellow flame is examined through a yellow color screen, it will

be found to be permeated by a thin blue flame and, if a supporting atmosphere is available, the yellow spot will be found to be entirely surrounded by blue flame. This is true also of flame spots of green, red and white, when each is examined through the proper color screen. In stable fuels green, red, yellow or white flame spots can be said to be the result of either temporary or permanent lack of oxygen. Thus, it appears that a transparent blue or lavender flame always indicates oxidation, while spots of any other color indicate either excessive cracking into new, smaller hydrocarbons, and the large production of CO, or the complete dissociation into free carbon and free hydrogen.

It will be found that if a given quantity of stable fuel is burned with an entirely blue flame, the flame occupies less space than when spots of any other color appear, provided too great an excess of air is not used. When a combustible mixture is of correct fuel-to-air ratio and the fuel is in the proper physical state, the resulting blue-flame combustion is much simpler, more complete and compact than any other. There is much evidence that carbon always burns immediately to CO_2, when it can secure the necessary air. In any event a normal blue-flame combustion will go to completion in less time and space than any other, thereby imparting all of its molecular forces to the gases early in the stroke and allowing a more complete expansion than is common.

It would not show any flame at the exhaust port. Only about 8 per cent of its energy is in the form of radiant heat, against 30 per cent or more in the luminous flame; it is incapable of making soot; and its progress is not affected seriously by contact with cold surfaces. As radiant heat has the same velocity as light, it is nearly 100 per cent loss in an engine cylinder; therefore it is the imperative duty of combustion engineers to devise a method by which present fuels can be burned with a blue flame.

Messrs. Woodbury, Lewis and Canby introduce experimental evidence which they believe shows autoignition of parts of the mixture ahead of the flame-front, which, under certain circumstances, is certainly possible. In the burning of rich mixtures of stable fuels and in the burning of unstable fuels in any fuel-to-air ratio, there is a great amount of dissociation from which an abundance of charged ions of every constituent of the mixture is produced. A pressure wave probably cannot be made to travel through molecular air in excess of the velocity of sound; however, there is nothing that prevents charged ions from greatly exceeding that rate. As spontaneous combustion can be started far below the ordinary ignition temperature of the fuel with oxygen ions and in many cases with hydrogen ions, there is no good reason for doubting that much of the so-called detonation or knocking arises from ignition of remote parts of the mixture by charged ions produced in the dissociation of the fuel. A reasonable degree of ionization of oxygen is of benefit in any combustion, but it should take place before combustion begins, as a sudden large production of ions during an explosive combustion is certain to produc undesirable results. This is another valid reason for the study and development of the blue flame in which dissociation is not a necessary event.

WILLIAM C. DAVIDS:—Has Mr. Fielder ever tried to heat the air between the carbureter and the engine, instead of heating it before it goes through the carbureter? I have found in practice that heating the air after the gas comes through the carbureter is far better than heating it before. Some years ago I experimented with hot-spots and used them in two-cycle engines carrying the hot-spot under the manifold and so heating it completely across. That heated the air and gas after it left the carbureter, and I think that is the proper way to apply the heat. The gas passing down into the crankcase of the two-cycle engine, receiving its heat from the pistons, was satisfactorily vaporized and we obtained exceptional efficiency from the engine.

MR. FIELDER:—We believe that heating the air between the carbureter and engine by the hot-spot method is undesirable because the temperature is uncontrollable due to the variations in the atmospheric temperature at different seasons of the year. This is a condition that we have tried to overcome. We all know that there are certain periods during the year when the average internal-combustion engine functions best, which is due to the atmospheric temperature being right, and we have tried to standardize this temperature throughout the year by use of the thermostat.

MR. SPERRY:—The fact is interesting that in the Diesel engine there is never any carbon monoxide to be found. I thought possibly that this might be a peculiarity of some work that we are doing and so sent our chemist to a Navy Yard where they are running Diesel engines of different sizes up to 700 hp. to analyze samples of exhaust gases. We now have analyzed many samples from engines running at 25, 50, 75 and 100 per cent of their rated load, and at 10-per cent overload. In none of those samples do we find the slightest trace of carbon monoxide. There is evidently some fuel saving there. In following out Mr. Chase's suggestion, if we are to compress the air, why not go somewhat further and produce auto-ignition, eliminating carbon monoxide entirely and at the same time rendering available a wide range of fuel and much cheaper fuel than gasoline.

I find that many engineers are afraid of high compression in an internal-combustion engine. Is it understood that, with the two or three rings that it seems wise to some engineers to add to get 500-lb. instead of 65-lb. compression, the piston will drop right through the cylinder of its own weight. There is no extra friction that amounts to anything and those pistons are coming out of long runs practically as good as when they started. Diesel engines are perfectly practical. There are thousands of them in operation. I venture to say that before this Hudson Vehicular Tunnel is complete we will have no carbon monoxide to cope with.

W. M. WALLACE:—I am indebted to Mr. Nelson for bringing to my attention the details of the results of his experiments with constant and variable-clearance aluminum pistons. The results of my own research to date, regarding this subject, indicate that the troubles with pistons are due basically to leakage around and under the rings and to lubrication difficulties. I doubt that joint leakage amounts to very much, compared with the leakage around and under the rings. Lubrication difficulties are accentuated in many instances by the apparent failure of designers to pay proper attention to the design insofar as lateral or wall pressures are concerned. There are also many other detail points, but these are not so important.

It is obvious that pistons should be as simple as is possible. The piston material preferably should have the same coefficient of expansion as, or less than, that of the cylinder material. Other views of the problem in certain cases, as in air service and in tractor and marine requirements where large and constant power is needed, indicate the necessity for some material capable of transmitting

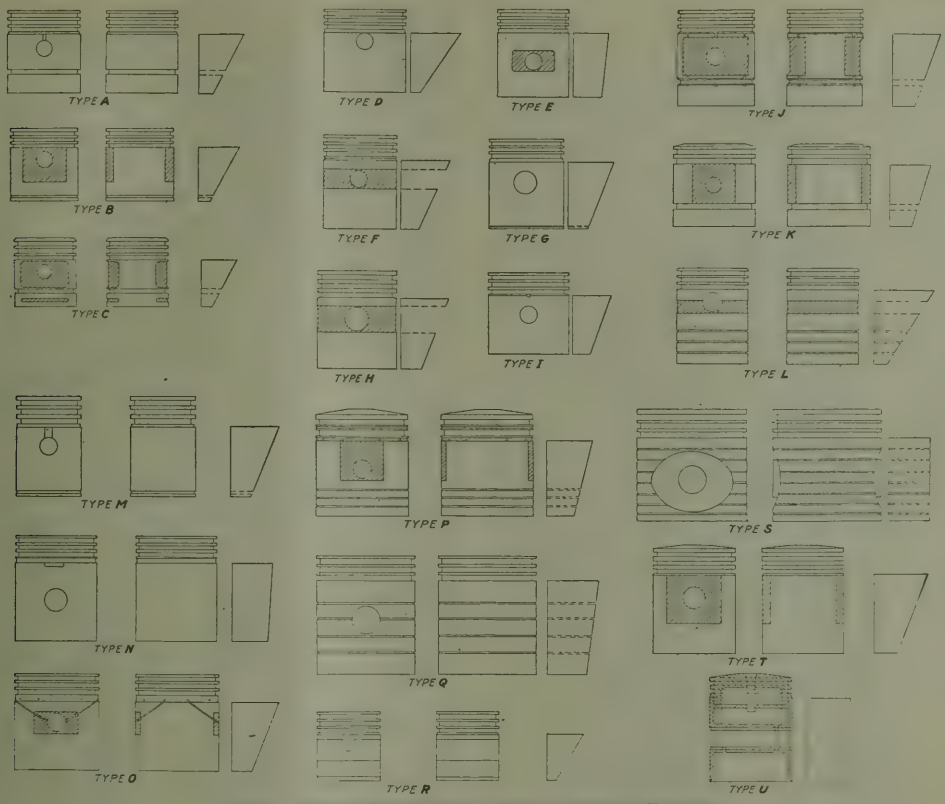


FIG. 5.—VARIOUS TYPES OF PISTON USED IN AMERICAN ENGINES

the heat quickly. To accomplish this alloys of aluminum usually are resorted to.

It seems that a false head of aluminum might be substituted for the more-or-less complicated and certainly more expensive type suggested by Mr. Nelson. It appears possible to attach such a false head by a single adequate fastening at its center, thus allowing the material to change form without distorting the light cast-iron shell, as is indicated for Type *U*, Fig. 5. With this exception the sketches shown in Fig. 5 are all taken at random from actual pistons of American-made engines. Some are old; some are more recent. They were assembled to show, so far as is practicable, the trend of practice regarding the provision for side-pressure. To make comparisons it was necessary to make a few assumptions, as follows:

(1) The thin surfaces above the bottom ring are neglected as bearing surfaces. This in most cases is certainly a fair assumption
(2) The material is considered rigid and not bending
(3) Friction of the piston against the cylinder wall and the wristpin bearing is omitted; these corrections are not only small but more-or-less self-compensating as the piston changes cycles
(4) The unit pressures indicated in the small sketches alongside of each type shown in Fig. 5 are obtained by the simple principle of the lever, assuming no bending, as mentioned in (2)

It seems logical that as a bearing crosshead Types *E*, *K*, *N*, *P*, *Q* and *S* would prove much better than the others. The remaining designs appear to predicate excessive wear above the pin, with a large margin of useless skirt. Inasmuch as the piston serves as the medium of converting the greatest amount of useful work from the combustion-chamber to the crankshaft, its tightness once and for all is imperative. Long service cannot be expected if the piston is eccentrically loaded as a bearing. Many engines are in use today with plain cast-iron pistons that have done years of yeoman service, but they were designed so that they wore very slowly in service and thereby maintained their efficiency. I believe that a reversion to plain light pistons which are accurately made and proportioned would in general be beneficial.

As regards the matter of reduction in weight of reciprocating parts, might it not be well to assure ample durability of the piston and cylinder wall, using such material and weight as may be necessary, and making such reduction as may be possible in the connecting-rods? Materials suitable for such forgings that are materially lighter than steel seem to show promise at this time.

Referring to the engine characteristics in connection with constant-speed driving, the interesting results indicate a geared fourth-speed. No doubt the excellent mileage claimed by many foreign makers is made possible by this fourth gear.

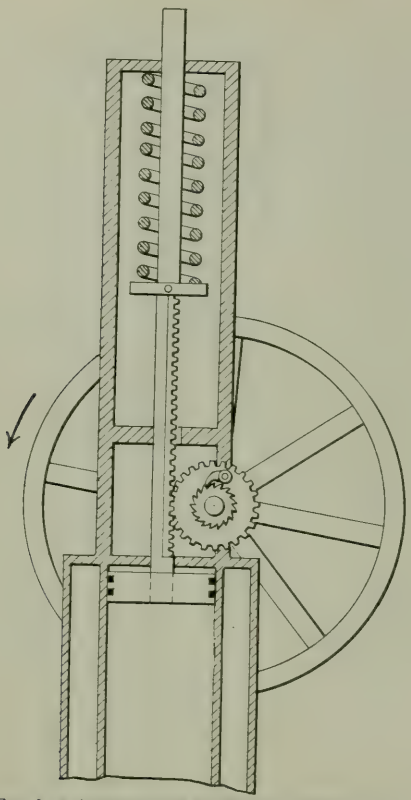


FIG. 6—A FOREIGN TYPE OF ENGINE IN WHICH THE HEIGHT TO WHICH THE PISTON IS THROWN BY THE IGNITION OF THE EXPLOSIVE MIXTURE IS REGULATED BY A SPRING WHICH ON THE RETURN STROKE DRIVES THE CRANKSHAFT THROUGH A RACK AND PINION

E. FAVARY:—It may be possible to eliminate the engine knock by mechanical means, and perhaps harness it or the indirect cause of it to increase the power derived from the products of combustion. According to indicator diagrams there is a rise in pressure in the cylinder that is so high and so rapid that it causes a knock. By reducing the compression pressure somewhat, the knock disappears. The sudden rise in pressure takes place at the beginning of the expansion stroke, when the piston velocity is comparatively low. It seems to me that by using a cylinder-head or a combustion-chamber that yields under a pressure beyond that normally occurring in the cylinder at full load and just below the pressure at which knocking occurs, the knock could be eliminated and the mean effective pressure increased.

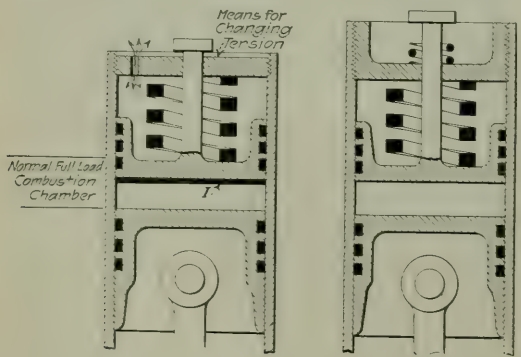


FIG. 7—SUGGESTED FORMS OF CONSTRUCTION FOR ELIMINATING KNOCKING IN AN ENGINE

Fig. 6 is an illustration of an engine I saw in operation in Paris during 1897. Upon ignition of the explosive mixture the piston is thrown up as fast and as far as the spring will permit; on the return stroke the spring alone drives the crankshaft through the toothed rack and the gear wheel of the crankshaft. This engine, as I recall, had extremely high thermal efficiency.

Fig. 7 shows constructions that might prove useful for eliminating the knock and increasing the mean effective pressure. The drawings are diagrammatic, the valves and spark-plugs not being shown. This construction embodies a combustion-chamber of variable capacity so that under a partially closed throttle there is the same compression as under wide-open throttle. With a partly closed throttle, when the maximum pressure arising from the combustion of the charge is lower, the auxiliary piston descends until the maximum pressure in the cylinder is substantially the same as at wide-open throttle. In this manner the compression pressure is regulated by the maximum pressure. Several methods suggest themselves for reducing this system to practice.

The drawing at the left of Fig. 7 shows a small vent-hole in the top of the cylinder which will have the effect, in a measure, of preventing the upper piston from rising or descending rapidly. Instead of having the vent-hole where it is shown, the stem of the upper piston could be made to slide in a small sleeve having a vent-hole; this might be better adapted to regulating the speed at which the upper piston rises or descends. Making the upper piston heavy also would be found advantageous, on account of increased inertia effect. The spring can be located at the outside of the cylinder, instead of where it is shown, and it can be made to operate on the stem of such piston. Instead of using a spring, air might be compressed and caused to act like the spring. With this particular construction, suppose the piston were in a certain position at half-throttle, and that suddenly the throttle were opened wide, producing the condition under which knocking occurs. After two or three revolutions of the crankshaft the upper piston would rise by virtue of the increased pressure in the cylinder. This would not necessarily be due to the high pressure of the knock, but to the increased normal maximum pressure, until the knock disappears.

In the right-hand portion of Fig. 7 the upper end of the cylinder is entirely open or closed and the piston is made very light to reduce its inertia, so that at each firing of the charge it will rise at first. The upper piston can be made to begin to rise at say a pressure of 150 lb. per sq. in.; let us assume that the compression is just below that where self-ignition would occur. After the ignition of the charge the piston would begin its upward course and the knock might even assist to force it up. Then, as the power piston descends during the expansion of the gas, it will follow the latter piston for some distance and thus keep up the pressure at the beginning of the expansion stroke. After the upper piston stops the

expansion curve drops rapidly. The high pressure that is just below the pressure at which the knock occurs will increase the flame propagation from what it would be if the pressure were lower, and the expansion curve will therefore more nearly follow the adiabatic law.

Means can be provided for changing the tension of the spring in any convenient manner to vary the compression pressure. It possibly could be changed from the dash. This system will show a higher volumetric efficiency and the combustion-chamber will be smaller during the exhaust stroke; hence a smaller quantity of burned charge will remain in the cylinder. It may be possible even to expel substantially the entire burned charge by having the upper piston descend farther than is shown at the right of Fig. 7. On the suction stroke we should obtain a higher vacuum at the beginning of the stroke. This would fill the cylinder more thoroughly and the piston-heads could be insulated also, to decrease the thermal losses still further.

Instead of having the pressure in the cylinder raise the piston and having it stopped by a spring, mechanical means interconnected with the shaft might be employed which could be regulated so as to increase the volume of the combustion-chamber at the beginning of the expansion stroke or during any portion of any of the strokes. By having a high compression prior to ignition at all positions of the throttle, a very great saving in fuel might be obtained.

T. C. MENGES:—I wish to state the experience I have had in running stationary engines on kerosene. These engines are equipped with a throttling governor and a high-tension magneto and spark-plug. The difficulty with a kerosene engine is to get it to run well on a light load, or on no load. Fig. 8 illustrates the results of my experience.

First, the carbureter should be placed above the inlet valve. We have placed the carbureter below and on the side, but the best location is up above as shown. The reason is that if any liquid kerosene drops down, it is drawn into the engine and does not form a slug when the throttle opens up for a heavy load. Another reason is that kerosene vapor will not rise easily; it seems to be a heavier vapor than gasoline, and will stick to the walls of the manifold. If we put the carbureter above the inlet valve, we do not require as hot a manifold or as hot an intake of air. This gives better volumetric efficiency and the engine will run more satisfactorily. The carbureter on an automobile engine is usually placed below the manifold; consequently we have the same trouble in handling the lower grades of fuel that we had with the carbureter when it was located below the inlet valve.

Second, the inlet manifold should be short. A manifold like that in Fig. 8 gives good results. In a long manifold unless the manifold is kept very hot, the kerosene vapor will condense and form a poor mixture. Curves and turns in a manifold should be avoided. No extra heating of the mixture is necessary when the manifold is short. It seems that if we can get the fuel vapor into the cylinder without condensation, the engine will run well. We are able to run engines on kerosene without a hot-air manifold, and we do not need to use water to keep down the knocks. This probably is due to the fact that the vapor enters the engine in a fairly cool condition.

Third, the most important point is the location of the fuel nozzle. All automobile-engine carbureters seem to have the nozzle in the center and separated a long distance from the butterfly throttle-valve. This is all wrong for utilizing kerosene, and I believe it is wrong for utilizing the lower grades of gasoline. In Fig. 8 it will be noticed that the nozzle is in the side of the air-pipe. What is of greater importance is that it is located within 1/16 in. of the edge of the butterfly throttle-valve. We have tried all different locations and none of them works so well as the one shown in Fig. 8. The nozzle should be very close to the throttle, but this is impossible with the ordinary type of carbureter. If the fuel nozzle is located as shown, the engine will run well at any load or speed.

When the engine is running on no load, the butterfly throttle-valve is almost closed, and what little air passes into the carbureter must pass the fuel nozzle. This breaks up the liquid fuel and forms an explosive mixture. I believe that if the liquid kerosene could be broken up into a fine enough mist, an engine would start cold on kerosene. On the other hand, if the kerosene is not thoroughly broken up, an excess amount of heat will be required to vaporize it. One should be sure to locate the fuel nozzle on the side which forms the bottom sweep of the turn, so that the air does not need to hold the liquid in suspension, as would be necessary if it were on the upper side.

The substance of my experience in running stationary engines is that the three important features in utilizing kerosene fuel are (*a*) to locate the carbureter above the inlet valve of the engine, (*b*) to use a short manifold with few bends, and (*c*) to place the fuel nozzle next to the edge of the butterfly throttle-valve.

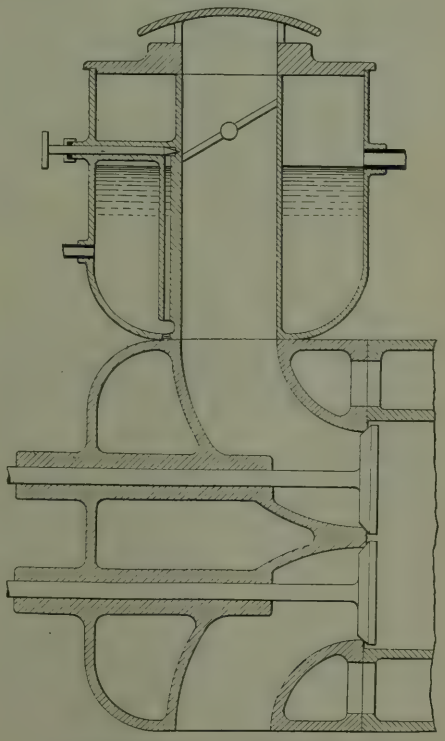


FIG. 8—SECTIONAL VIEW OF A PORTION OF A STATIONARY ENGINE DESIGNED TO BURN KEROSENE

G. HAMILTON GRAPES:—In reference to the fuel problem, the following improvements are needed to afford free growth to automotive plants and national production.

(1) A halt to further dilution of standard gasoline by fractions having end-points above 400 deg. fahr.
(2) The addition to standard gasoline of 10 per cent of benzol or 20 per cent of alcohol, or proportions of both
(3) The raising of all engine compressions by 10 per cent
(4) The employment of smaller and more efficient engines, and the lightening of chassis and bodies. All of this would represent a probable further 10-per cent increase in fuel efficiency and conservation
(5) The absolute gasification of the higher-boiling fractions, and the maintenance within minimum limits at maximum efficiency, by suitable automatic apparatus, of the temperature of the gaseous mixture prior to its entry into the engine cylinders. This would prevent the present waste of 10 per cent of standard gasoline now so evident in the excess of carbon monoxide and dioxide products in city service, in the dilution and deterioration of engine lubricants and in carbon deposits throughout the explosion chambers and in the gas exit passages of internal-combustion powerplants
(6) That the oil companies are best fitted by their organization to place economically upon the market a standard power fuel compounded with alcohol at a controlled price limit. Their cordial cooperation and coordination with the Society of Automotive Engineers in its efforts to solve this problem are most desirable, in the best interests of the public
(7) That the Government should install forthwith a laboratory, personnel and equipment to be entirely devoted to research work in compounded liquid fuels. This work should deal with constituent parts including alcohol, petroleum, benzol, shale oil and any other suitable medium. This activity should be supplemented by the production of power alcohol upon a limited commercial basis by State agricultural experiment stations
(8) The prohibition by the health authorities of the present fuel wastage by the emission of excess noxious gases by any motor vehicle, the result of incomplete combustion. This should be on the ground of danger to the public health
(9) A tax upon all cars weighing more than 2000 lb., or having a seating capacity of more than four adults. The proceeds should be allocated to fuel research work. This should reduce considerably the present loss in the transportation of non-profit-earning tare-weight which is now a fruitful source of gasoline wastage. If enforced, this tax would effect a fuel saving of at least 5 per cent

Upon a conservative basis, it is reasonable to suppose that if these outlined suggestions were given a thorough trial, a saving of 40 per cent would be effected in the liquid-fuel supplies of the United States.

H. L. HORNING:—I had Mr. Nelson's advance experimental notes, and I examined the performance of the engine. From the size of the engine and the compression ratio of 5 to 1, it seemed that the combustion efficiency should be 66 per cent or, in the more usual terms, the indicated thermal efficiency should be 66 per cent of the air-cycle efficiency. The air-cycle efficiency, which is a standard by which engine performance can be judged and is based on a fundamental characteristic of an ideal working fluid, is 47.5 per cent of the total energy in the fuel for a 5 to 1 compression ratio. Therefore, 66 per cent of this would be 31.3, which is the indicated thermal efficiency. On examination of Mr. Nelson's results I found that he attained this efficiency at 2100 r.p.m., the speed at which the gas velocity through the intake valve usually produces the highest thermal efficiency in overhead-valve cylinders. He started out to accomplish the elimination of the knock, the highest horsepower performance and the greatest possible ton-miles per gallon of fuel, in an engine. Mr. Nelson is to be congratulated on having practically accomplished these three results on his given product.

The lesson we can draw from his results is that by using a much smaller engine and thus limiting the horsepower still greater results in useful work can be accomplished. This is not a criticism of his paper; it is making the most of the information and conclusions undoubtedly indicated by the paper. In examining the curve of indicated thermal efficiency at speeds of 1000 to 1400 r.p.m., it will be noted that it rises very rapidly. This indicates that the turbulence at these speeds is very low, and it is not until the engine attains 2100 r.p.m. that we reach the highest efficiency. At the speeds just below 2100 r.p.m. however the curve of the indicated thermal efficiency rises with comparative rapidity and exceeds a 3-per cent range in 600 r.p.m. This indicates that the combustion efficiency has been neglected for volumetric efficiency. A lower-lift valve would have given a higher gas velocity and a greater efficiency at lower speeds, without sacrificing the volumetric efficiency in a marked degree and therefore sacrificing the horsepower. Mr. Nelson was able to get down to 0.51 lb. per b.hp-hr., which is a very credible performance, but it is possible for him to attain a fuel consumption of 0.48 lb. per b.hp-hr. by increasing the combustion efficiency as suggested.

MR. NELSON:—Mr. Horning has carefully studied my paper and offered some very constructive criticism. The best performance of the engine does not come at full load; it comes at about 90 to 95 per cent of the full load. Under those conditions the economy will equal that of Mr. Horning's expectations. I have tried 0.375-in. valve-lift. The loss of maximum power is slight. A close comparison of results along Mr. Horning's line of suggestion has not been made, but it should prove very interesting. The striking feature of Mr. Horning's work is his ability to determine with great accuracy the results that should be obtained. It is clear to me that his work on turbulence is bearing fruit.

MR. HORNING:—In reference to Mr. Fieldner's paper, as liquid fuels have increased in end-point or decreased in volatility, a number of difficulties have developed in the operation of engines which are familiar to all. Among them are

(1) Difficulty of starting at low atmospheric temperatures
(2) Poor acceleration immediately after starting, particularly in cold weather
(3) Low miles-per-gallon performance
(4) Rapid deposits of carbon on the combustion-chamber walls
(5) Rapid wear of rings, piston-ring grooves and cylinder walls, due to diluted lubricating oil on the cylinder wall
(6) Dilution of the crankcase oil with the heavier constituents of the fuel and products of combustion
(7) High consumption of lubricating oil, due to a thinning of the oil by the fuel

These are the common forms of complaint and difficulties that are experienced with modern fuels. There are other ways in which the performance of the engine is affected. These need not be discussed at this moment.

An analysis of all these results indicates that they arise largely from the incomplete vaporization of the fuel in time to be of value in producing power.

Outside of the tendency of the great bulk of the fuel available in the world to cause knocking in the engines and thus limit the power available from these fuels, namely the paraffines and olefines, the problem of vaporization is the most important one from the standpoint of conservation which confronts the engineer. It is therefore interesting to consider how the efficiency of vaporization can be ascertained. The indicated thermal efficiency of any engine is the percentage of the total energy of the fuel left after deducting the losses due to volumetric considerations and the loss of effective gaseous fuel due to poor vaporization. Carburetion efficiency is the ratio of the fuel actually burned to that supplied, or the ratio of the energy found in the indicated mean effective pressure to the energy which should be found in the mean effective pressure if all the fuel were burned. A way by which carburetion efficiency can be ascertained is testing an engine with a very volatile fuel, one which approaches as nearly as possible the form of fixed gases at practical temperatures. The most convenient fuels to use for this purpose are the better grades known as "aviation gasolines"; the standard test fuel should contain enough of the napthenes and aromatics to remove the possibility of detonation, auto-ignition or preignition. The procedure is to make a test of engines at the various speeds and loads with these better gasolines, finding the indicated thermal efficiency attainable under these various conditions. By dividing the indicated thermal efficiency by the air-cycle efficiency, the relative efficiency, which can be considered as a combustion efficiency, is ascertained. In this combustion efficiency we have a standard by which we can judge the performance of any engine and any fuel. The use of this standard is indicated by the following fundamental statement.

There is a limited range of air-to-fuel ratio by weight which can be fired in an engine. This varies from 8 to 1 to 18.75 to 1. With a fuel having a B.t.u. content of approximately 19,400 per lb., a mixture of perfect proportions has a ratio of 15 to 1. The maximum heat that it is possible to liberate is controlled by the oxygen present in the mixture. With a mixture having less fuel than the amount demanded by perfect chemical proportions, the amount of heat liberated is measured by the amount of fuel present. It is obvious, therefore, that the amount of heat liberated in any mixture, from the leanest that can be fired up to the chemically perfect mixture, is proportional to the fuel content of the mixture. Because any fuel over the amount necessary to consume all the oxygen cannot burn, this excess is of no value in producing heat and merely acts as a diluent, the same as an excess of air acts as a diluent. Since 1 lb. of air at normal temperature and pressure has a volume of 13 cu. ft., and it takes 15 lb. of air to burn 1 lb. of fuel, 195 cu. ft. of air is required for 1 lb. of fuel. Therefore, in 1 cu. ft. of mixture there are 19,400/195 or 100 B.t.u. Considering the cylinder to have a volume of 1 cu. ft., and the piston an area of 1 sq. ft., on the assumption of no losses, we would have the following thermodynamic relationship:

$$PV = W = FS$$

where

P = average pressure in pounds per square inch
V = volume range in cubic feet of mixture
W = work done in foot-pounds
F = average force in pounds
S = space range in feet

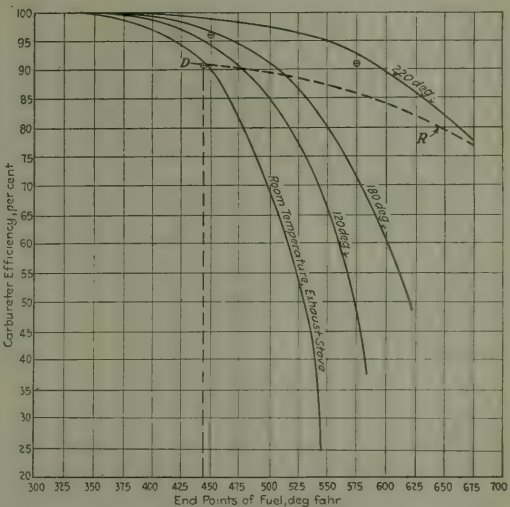


FIG. 9—CURVES SHOWING THE RELATION BETWEEN CARBURETER EFFICIENCY AND THE END-POINT OF THE FUEL

Thus in 1 cu. ft. of mixture we have as indicated above 100 B.t.u. If we multiply this by the constant 778 ft-lb. per B.t.u., we have the total number of foot-pounds of energy in 1 cu. ft. of standard mixture. If we divide this by the number of cubic feet, we have the number of pounds per square foot and, since there are 144 sq. in. in 1 sq. ft., we can thus derive the number of pounds per square inch by dividing the number of pounds per square foot by 144, or

$$P = E \div (144 \times 1)$$

where

P = the average pressure in pounds per square inch
E = the energy content of 1 cu. ft. of the correct mixture

Hence

$$P = 77{,}800 \div (144 \times 1)$$
$$= 45$$

Since the amount of mixture drawn into the cylinder is always less than the swept volume, due to the restriction of the intake valve, the manifold and the carbureter, and the temperature, the pressure obtainable would be reduced to that corresponding to the volumetric efficiency. If we calculate the indicated thermal efficiency from the air-cycle efficiency by using the combustion efficiency attained when using a perfect fuel as indicated above, we will find, with the less volatile fuels, that the following relationship obtains:

$$ITec \times E \times V > IMEP$$

or

$$Ae \times Ge = ITec$$

where

$ITec$ = the calculated indicated thermal efficiency
E = the number of British thermal units per cubic foot multiplied by 778 and divided by 144
V = the volumetric efficiency ascertained by measuring the weight, at standard temperature and pressure, of the air actually used, and dividing this by the swept volume of the engine

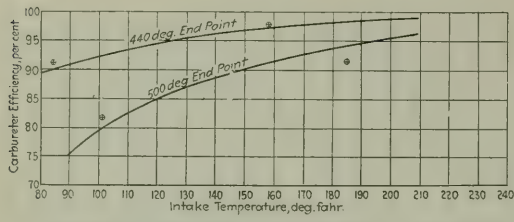


FIG. 10—CURVES SHOWING THE RELATION BETWEEN THE CARBURETER EFFICIENCY AND THE INTAKE TEMPERATURE

$IMEP$ = the indicated mean effective pressure actually attained in the engine
Ae = the air-cycle efficiency
Ge = the carbureter efficiency

Therefore

$$Ge = IMEP \div (ITec \times E \times V)$$

In the days when the fuel had an end-point of less than 300 deg. fahr., the carbureter efficiency was very high. In those days the accidental heat given to the fuel in the carbureter and by the manifold, and the heat of the air, or in the cylinder, was sufficient to evaporate practically all the fuel. As the fuel began to recede in volatility, 300 deg. fahr. being the approximate initial point of kerosene, the manifold became more important as a means of supplying the heat essential for vaporization, and it was found necessary to heat the air to insure vaporization. With the next decrease in the volatility of the fuel, it became necessary to heat the manifold; and a considerable amount of the fuel was evaporated inside of the cylinder. On still further decrease in the volatility of the fuel, the manifold temperature assumed still greater importance and the cylinder reached the limit of its ability to evaporate the liquid fuel entering it, in time for effective combustion. With kerosene as fuel, the highest temperatures of the manifold and the cylinder practical in operation are necessary for reasonable carburetion efficiency. The fundamental consideration in the designation "carburetion efficiency" is that the function of the carbureter as originally intended to vaporize the fuel as well as meter it has been spread from time to time toward the piston of the engine. Therefore, while the carbureter is not now performing the function of vaporization, other elements in the engine are pressed into service to accomplish this result. It is thought proper to call the efficiency of vaporization "carburetion efficiency." The letter G is used to denote the fundamental necessity of having the fuel in the form of a gas. We can assume that the cause of low thermal efficiency in modern engines burning the heavier fuels at compression ratios below that of detonation, is due to low carburetion efficiency.

Notwithstanding that the temperature of the ingoing mixture is only approximately an index of its condition, this index gives us a basis on which to chart the efficiency of vaporizing systems on modern engines. Since it is the index of the atomization of the fuel at the nozzle of the carbureter and the vaporization in the intake manifold, it is a fair basis of judgment of different systems of vaporizing. Since the end-point of various fuels is associated with that proportion of fuel which resists vaporization, this can be taken as an indication of the fuel value from a vaporization standpoint. If we take an engine or a series of engines with different kinds of carbureters and vaporizing systems and list them with respect to the temperature of the ingoing charge, we have a basis for testing one of the fuels available. Testing this fuel, we will find that, as the intake temperature increases, the carburetion efficiency also increases within limits. If we take a number of fuels having increasing end-points, and plot the results of these different fuels with different systems, we will have a complete graph of the effect of different systems of vaporizing with fuels of different end-points on carburetion efficiency (See Figs. 9 and 10).

In Fig. 9 the point D on the room-temperature exhaust-stove curve, denoting the system used on the Ford, is a very interesting point and of equal importance to the automotive and the petroleum industries. This point is the end-point of the standard gasoline according to the present Government specifications, and happens to be at such a place on the curve that a 10-per cent increase in the end-point will represent a 10-per cent decrease in the carburetion efficiency. The result is that there would be no economic gain, inasmuch as there would be no power delivered for the additional fuel bought or supplied. By running the line of 440-deg. end-points vertically through the other curves, we have the 440-deg. end-point curve of Fig. 10 which, interpreted, means that for any further increase in end-point there will have to be a corresponding increase in the intake temperature. If, in Fig. 9, we investigate the curve of 180 and 220-deg. intake temperatures, we will get a curve ending in R. This curve is what is known to economists as the "curve of diminishing returns." The line shown is for full load and at 1000 r.p.m. and, since the carburetion efficiency is highest at full load and higher speeds, this D-R line represents the maximum attainable. Ascertaining the D-R line for various loads and speeds would give all the vaporization data necessary and when determined from actual conditions would be of immense value. I submit that this is exactly what the automotive and the petroleum industries desire to know. Perhaps the public desires to know it more than anyone else.

I submit that this is the curve which should be the object of our immediate research efforts. It is the common ground on which the industries involved and the

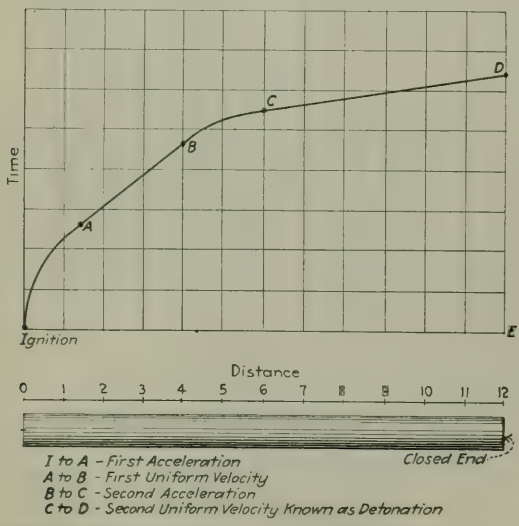


FIG. 11—DIAGRAM SHOWING THE VARIOUS STAGES IN FLAME PROPAGATION IN A TUBE HAVING A CLOSED END

public can measure their exact position. It is the only curve by which designers of automotive apparatus can direct their efforts, as well as the only curve by which the petroleum industry can tell whether additions of heavy fuel are of any value to the public when used in the apparatus available. A meeting of the Joint Committee of the Petroleum and Automotive Industries, the Bureau of Standards, the Bureau of Mines and the Society of Automotive Engineers unanimously approved a program of fuel research to be supported by these agencies of which Figs. 9 and 10 illustrate a skeleton representation of procedure and objective. It seems certain that the most urgent immediate research is the efficiency of vaporizing systems with respect to the increased specific gravity of fuels.

With respect to the problem of applying the theories of flame propagation to the phenomena which occur in the cylinders, the following is a theory that our company has developed and used in research work. Referring to Fig. 11, *I-E* is a pipe in which a combustible mixture is ignited at the point *I*. As flame travels along the pipe toward the end *E*, the velocities change according to the order hereinafter described. An examination of a large number of flame photographs indicates that there are four possible phases in the velocities of the flame in a tube of uniform cross-section, not all of which are apparent, but which are approximated in nearly all mixtures. The four phases through which the velocities pass are as follows: As the flame travels from *I* to *A* it accelerates; this period is known as "the period of first acceleration." As the flame travels from *A* to *B*, it takes a uniform velocity. This phase is known as "the first phase of uniform velocity." As the flame travels from *B* to *C*, it passes through its second acceleration, and is so known. As the flame travels from *C* to *D*, it attains a uniform velocity and continues at this rate, which is known as "detonation." The use of a tube in the study of flame propagation is merely a device for drawing out the process of ignition, and for developing these four phases of flame velocity. The tube tends to establish the condition of quiescence and thus remove such artificial physical factors as stimulate the rate of reaction outside the condition of temperature and pressure. Since the flame travels into an entirely fresh mixture undiluted by products of combustion, the mixture is successively subjected to a rapidly increasing condition of temperature and pressure restrained by constant area of the flame crest, the chemical stability of fuel and dissociation.

However, it seems probable that with all hydrocarbon fuels, after a certain velocity of flame is reached, the catalytic action of the hydrogen ion has a decided influence on the rate of flame propagation, and it is entirely probable that an incandescent particle of glass may initiate some of the changes in velocity. Sound-waves traveling through the mixture tend to add compression effects and they can be seen traversing the regions of partial combustion, causing increased brilliancy of flame, and thus can be considered as augmenting combustion. Whatever phenomena may exhibit themselves in the idiosyncrasies of flame velocities can be considered as the resultants of all these factors.

For the practical man, we can set forth some seeming certainties based on thermo-chemistry. The region *B-C* represents a condition of combustion which, if it were possible to attain homogeneity throughout the mixture, would produce the highest thermal efficiency. The successive stages of *C-D* represent an increasing presence of too rapid a combustion of some of the contents, with the resultant incandescence of solid carbon particles. These represent an increasing loss due to direct radiation and, no doubt, the heat affects the regions of unburnt mixtures and accounts for a rapidly increasing reaction in these regions of flame. The point *C* also is favorable from a dissociation standpoint and may therefore symbolize the best compromise in practice between the controlling chemical and physical factors with respect to the highest thermal efficiency.

Phase *A-B* can be considered as the rapidity of combustion corresponding to lean mixtures and low loads

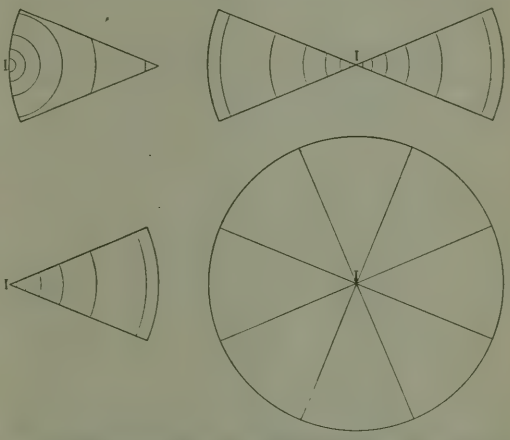


FIG. 12—DIAGRAM SHOWING THE INCREASE IN THE AREA OF THE FLAME CREST IN DIFFERENT FORMS OF COMBUSTION-CHAMBER

and, from a thermodynamic standpoint, is characterized by a smooth sweet running of the engine.

Phase *B-C* can be considered to represent the combustion of the most economical mixtures at loads at and under that giving maximum economy, provided there is no marked or incipient auto-ignition. This is at nearly full-load performance and with lean mixture of low-compression engines down to normal running. This performance is not characterized by any roughness.

Phase *C-D* is characteristic of the engine having a compression just low enough to avoid detonation at the most economical mixture, but which is running with a richer mixture. This may also be representative of an engine running when the ratio is somewhat too high for available fuels; running at full throttle either accelerating or at full load. The action corresponding with this is a very rough performance and the effects can easily be felt as well as heard.

Phase *D-E* is one represented by the very rough performance of an engine in which the compression ratio is too high for the fuel available, the engine running at full load on a perfect mixture, and is about as rough as can be imagined. The roughness is greatest at a speed of maximum torque, which is at relatively slow speed.

The first phase is one in which the flame is of a blue color. The second phase increases in intensity of color and sometimes approaches green, and this is the very best and most efficient type of combustion. The third phase is one in which a yellow color is emitted from the flame, and the fourth one in which the flame has a brilliant white appearance.

A tube has the limiting feature of a small uniform

cross-section and it therefore is obvious that the only way in which a given volume of explosive mixture can be consumed in a relatively short time is by the use of a high velocity of the flame crest. Inasmuch as the efficiency of combustion is represented by the velocities not exceeding *C*, the problem of combustion in an internal-combustion engine resolves itself into a resort to other means of increasing volume consumption than by flame velocity. The theory used and developed by us is the theory of maximum areas. This involves the simple geometrical fact that a volume is generated by an area sweeping through a given distance. In other words, in a quiescent mixture the most effective way of consuming the greatest volume of it in the shortest space of time is to provide a shape of chamber in which the flame surface or crest can spread out, developing at each successive advance an increasing area of contact with the unburned mixture. Referring to the upper left portion of Fig. 12, in which we have a conical-shaped chamber and in which the lines drawn are the successive positions of the flame crest at uniform intervals of time in the form of chamber shown the area of the crest decreases very rapidly. In the lower left corner, with ignition starting at *I* and with lines representing the advance of the flame in equal divisions of time, we have a form which favors the development of a large area of the crest with each successive advance of the flame. It can be shown that the volume consumed in this form increases as the cube of the distance from the firing point and, since the distance traveled may vary in some mixtures roughly as the cube of the time, it will be seen that great volumes can be consumed in very short intervals of time. This high rate of volume consumption is based on the assumption that the flame is traveling into unburned mixtures and does not take dissociation or dilution into consideration. If we make a figure of two cones, starting the ignition at the peak as shown, the flame will then travel out as indicated and we will therefore have consumed twice the volume of mixture in the same length of time. If we generate a sphere with a great number of cones and ignite the mixture at *I* at the center, we will consume the greatest possible volume in the given time. It has been found by tests of explosive mixtures in vessels having approximately the form of a sphere that the rapidity of rise in pressure is maximum when the mixture is fired at the center, and at a minimum when the mixture is fired at one side. All these considerations have been based on a quiescent mixture.

The next expedient which suggests itself is that of furnishing many points of ignition. This again affords a means whereby great volumes of explosive mixtures can be fired without reaching high unit velocities of the flame at any point of the mixture. Thus, the diagram in the lower right-hand corner of Fig. 12 can be conceived to be a sphere of very small diameter and with many ignition points, we have many spheres merging into each other.

The other means available for increasing the volume of explosive mixtures consumed in a given time is stirring up the mixture and producing in it what is known as turbulence. If we produce a rapid enough circulation of the gases, it is possible by igniting them at the point of greatest rapidity of movement to approach approximately the effect of a multitude of ignition points. With this large number of ignition points distributed throughout the mixture, it is possible to initiate numerous spheres of flame and therefore an infinite number of small velocities and rapidly increasing flame areas and hence the maximum volumes in a unit of time without approaching the flame velocities of detonation. There are other considerations such as the area-volume ratio and the fact that spark-plugs have to be situated at the outside of a sphere. These need not be discussed here, other than to call attention to the fact that, because of the cool layer of gas on the walls of a combustion-chamber, turbulence insures a larger volume of gas consumed in a given time by driving the surface gas off into the flame and thus replacing it with the burned products of combustion. In a sphere the relative volume of these layers is minimized.

The process of turbulence is merely a physical assistance to the process of chemical reaction by assisting the kinetic tendencies of one species of molecules to make contact with those other species with which they must unite under the conditions in the cylinder. The process of chemical reaction of which combustion is one type is a surface phenomenon. The most modern conception of the constituents of the atom is that the electrons in the outside layer are the ones which give the atom of molecule its chemical properties. Therefore, when we develop the maximum of flame-swept volume by adopting those shapes of combustion chamber which will allow the most rapid development of flame-crest area for both mixtures of a relatively quiet nature and those aided by turbulence, we follow the most fundamental law of chemistry. In very slow combustions the reaction of hydrocarbons is in very many steps; as the reaction increases in rapidity the chemical stages through which a unit volume of mixtures pass become more direct, and it seems from all known considerations that the most thorough and best-controlled combustions are those in which the combustion-chamber can be considered to be filled with a mixture comprising a large number of small volumes in which the initial and end-stages of combustion are occurring at one time, intermingled with the products of combustion and their dissociations. There should, therefore, be a general homogeniety throughout the mixture rather than a progressive change of reaction from one part of the mixture to the other. The ideal condition would be that in which the various reactions going on in any small unit section at any one time are typical of those in a section of similar size in any part of the mixture. This is the very antithesis of the conditions in a tube.

There are three kinds of knock which are vaguely understood

(1) The knock which comes by igniting the charge too soon, and this can be produced either by the ignition system of the engine or by some hot-spot in the combustion-chamber
(2) The knock caused by pure detonation or, in other words, what occurs when an engine is running very slowly and the flame traveling in a mixture that is approximately quiescent
(3) The knock produced by auto-ignition, due to the shape of the combustion-chamber with a slow-burning mixture in which a virtual pocket of unburned gases fails to burn by the time maximum temperatures are reached; or, due to fuel left over at the high-temperature point, because of slow-burning mixtures; or, due to a two-stage combustion or a combination of all three of the above causes.

I know of no chemical reaction which turbulence does not assist in such an orderly way as to control materially the causes of knock listed above.

Aeronautic Propeller Design

By F. W. Caldwell[1]

Annual Meeting Paper *Illustrated with* Charts and Drawings

THE tendency of propeller design in the United States, France and Germany has been toward very narrow blades with extremely narrow tips. The British have adopted narrow tips but have not gone as far in making the main portion of the blade narrow with respect to the diameter. The use of these blades has been arrived at principally by the method of trial and

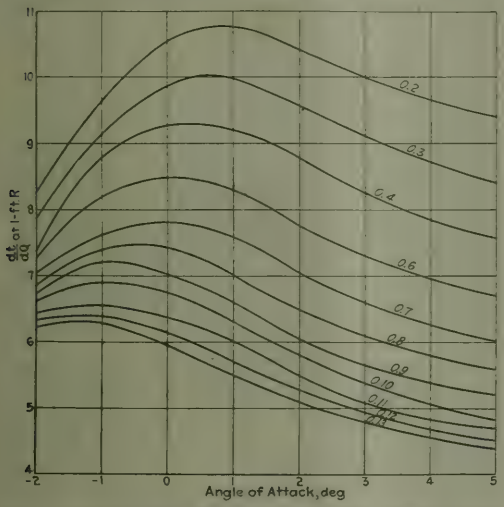


Fig. 1—Optimum Angle of Attack for Various Breadth Ratios for a Section Having a Camber of 0.09

error; experience having demonstrated that such blades give better performance in climbing and at top speed. The inflow theory, however, gives an indication that it is better with fast turning low-pitch propellers to use a somewhat narrower blade than has been customary on account of the fact that the optimum angle of attack for the various stations approaches more nearly the angle of attack for the best L/D. This is brought out by the chart in Fig. 1.

In speaking of the width of propeller blades as a whole, it has become customary to refer to the ratio of the tip radius to the maximum blade width as the aspect ratio. This aspect ratio has increased in our best propellers for fast turning engines from about 5 to about 7. In considering individual elements of the blade, however, the ratio of the sum of the blade widths to the periphery at the station under consideration is usually taken as a criterion of blade width and is written $B/2\pi R$. This quantity is called the breadth ratio and is analogous to the ratio of developed area to disc area used by naval architects. Fig.

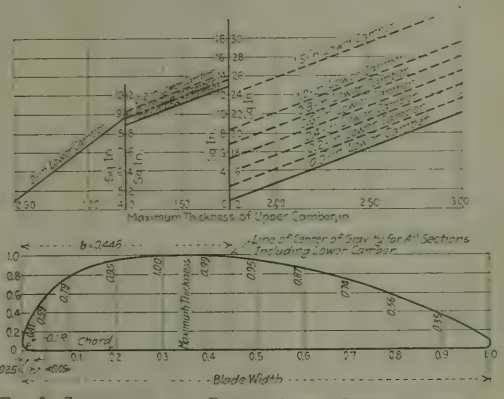

Maximum Thickness of Upper Camber, in
Line of Center of Gravity for All Sections Including Lower Camber
Maximum Thickness
Chord
Blade Width

Fig. 2—Coordinates of a British Airfoil Section Adopted for Use on Army Propellers

2 shows the coordinates of an airfoil section of British blades has to be varied considerably according to the ser- origin adopted for use on the Army propellers. As the camber ratio is varied at different stations along the propeller blade the section is generated from that shown in Fig. 2 by varying all the ordinates in proportion to the maximum thickness. The plan form of propeller vice of the propeller and the material for which it is designed. The upper portion of Fig. 3 shows a very good plan form, originated by H. C. Watts, of the British Air Board, which is very successful up to tip speeds of

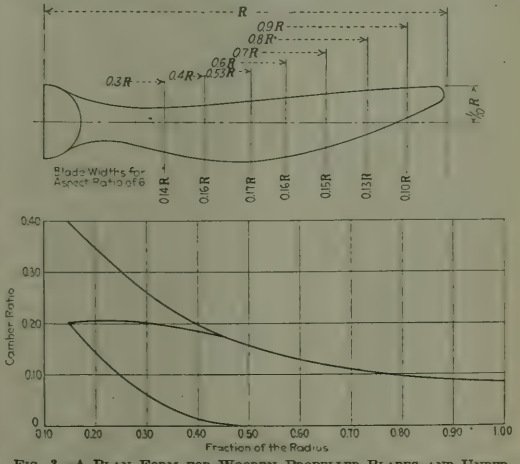


Fig. 3—A Plan Form for Wooden Propeller Blades and Underneath the Minimum Camber Ratio for This Form of Propeller at Various Stations

[1] M.S.A.E.—Aeronautical engineer, technical section, Air Service, Dayton, Ohio.

about 800 ft. per sec. and up to about 400 hp. Up to this speed and power this plan form is very satisfactory for wooden propellers in connection with the thickness ratios shown in the lower part of this illustration. For higher speeds and horsepower a similar plan form may be used, but these thicknesses will have to be increased in most cases. Fig. 4 in the upper section shows a plan form adopted by me for use in Micarta propellers while the lower portion shows a form recommended for steel propellers having an aspect ratio of 9.

For reversible propellers the above plan forms can be

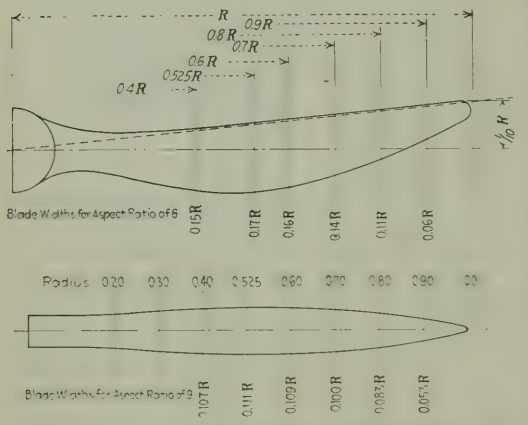


FIG. 4—PLAN FORM (ABOVE) FOR A MICARTA PROPELLER BLADE AND (BELOW) ONE FOR A BLADE MADE FROM STEEL TUBING

used as far as the variations in blade width are concerned, but it is very desirable for reversible propellers to space the centers of gravity for all the sections along a radial line perpendicular to the axis of rotation. If this is done the centrifugal moments are entirely eliminated except insofar as they are produced by the deflection of the blade. This arrangement, however, gives stresses which are symmetrical when the propeller is reversed. In other words, when the propeller is reversed the deflection still produces a centrifugal restoring moment, and since there are no initial centrifugal moments the stresses are similar to those in the forward pitch position. This arrangement does not remove all of the torsional moments from centrifugal force as can be seen from the discussion of reversible propellers.

In the case of engines of small horsepower considerable advantage in performance can be obtained by varying the plan form to suit the particular needs for which the propeller is to be used. For example, the straight leading edge has a torsional moment resulting from air pressure which tends to increase the pitch and a torsional moment resulting from centrifugal force which tends to increase the pitch. This plan form is especially suitable to ceiling propellers as there is comparatively small drop in the speed of the engine in climbing from the ground level to the ceiling, owing to the gradual decrease in pitch as the thrust decreases. The propeller is, however, not well adapted to meet the conditions of climbing and top speed near the ground, as the pitch decreases at top speed, causing a greater increase in revolutions between the climbing condition and the top-speed condition. One plan form is very well suited for climbing and top-speed conditions, but is not very well suited for ceiling. This plan form and elevation give an arrangement of the center of gravity line which causes the pitch to decrease as the result of the thrust and also as the result of revolutions. As the thrust decreases in going from the climb to top speed the pitch is increased, so that the engine shows a comparatively small gain in revolutions at top speed. The form is not very well suited for ceiling, since the pitch increases as the thrust drops off at ceiling, causing great loss of revolutions near the ceiling. Another plan form which is especially well suited to Micarta propellers as applied to supercharged engines shows a decrease of pitch as the result of the thrust and an increase of pitch as the result of revolutions. As a result, there is a very small gain in revolutions between the top and the climbing speeds. With the ordinary type of engine there is a considerable decrease in revolutions during the climb between the ground and ceiling, but with the supercharged engines there is an increased pitch at high altitude as the result of the drop in the thrust, and also as a result of the increase in revolutions, which is an exceptionally valuable feature. The French have shown considerable skill in the choice of a plan form to accomplish given results by this method which has been successful with small engines. With engines of 400 hp. and over, however, it is not always possible to choose the plan form in view of the performance as there is some difficulty in obtaining a smoothly running propeller free from flutter for these large engines.

Fig. 5 shows a nomogram worked out by Mr. Watts from which the best diameter for given horsepower and engine and plane speeds at ground level can be obtained. This nomogram is very satisfactory for use in connection with the wooden plan form shown in the upper part of Fig. 3, with an aspect ratio of 6 but for this plan form with other aspect ratios and for other plan forms the nomogram is not applicable.

A model test on one of the propellers adopted by Dr. Olmstead showed a maximum efficiency of 88.5 per cent, which is the best result I know of in a practical propeller. Unfortunately, structural considerations have not permitted a very wide application of this type of propeller. It appears probable that this type will be very successful when reduction gearing is applied to very large engines, and it ought to be extraordinarily good for dirigible balloon work.

It is, of course, impossible to go into propeller design very much in detail in a paper of this kind. It may be said, however, that the airfoil theory in connection with the inflow theory has given some very good results and proved to be very valuable for the aerodynamic design of propellers. Both theories have to be applied in the present state of knowledge with a number of empirical factors determined in practice.

PROPELLER THEORIES AND AERODYNAMICS

The basic theory of propellers, at least as far as aircraft propellers are concerned, has been built upon the elemental or strip theory which is due to Drzewiecki. This method of studying the propeller consists of dividing the blades up into zones of given lengths as shown in the upper part of Fig. 6, and assuming that each zone is an airfoil section having certain resultant pressure coefficients at various angles of attack, and a given direction of pressure at each angle of attack. The conception of angle of attack and the direction of resultant pressure are shown in the lower left corner for a given section. In studying propellers by this method, the work absorbed and delivered by each of the sections is

computed and the whole added up to give the total work absorbed and delivered. The efficiency obtained by this method was observed at the start to be far too high and the method was supplemented by the addition of the inflow conception in which the slipstream and race rotation created by the propeller are taken into account.

If v denotes the resultant velocity imparted to the air by an element of a propeller blade and M denotes the mass of air passing through the annulus generated by this element, in a unit of time, then the resultant pressure P on the element is equal to M times v. This is simply the law of impact resulting from fluid passing through the propeller at the disc. It should be borne in mind, however, not only that the resultant pressure P is equal to the product $M\ v$ but that the direction of the resultant pressure P must be opposite to the direction of the resulting velocity v, since action and reaction are equal and opposite. Based on this conception, the mathematicians have gradually evolved the theory that has been worked out in a most complete form by Dr. George de Bothezat.[2]

It would go beyond the scope of this article to go into the derivation of these theories in a very comprehensive manner, but I have tried to give the simplest possible discussion of this theory with the resulting equations. The simplest case of the inflow theory applies to the propeller at fixed point and the diagram for this condition is shown in the lower right corner of Fig. 6. The width of a single blade at a radius R from the axis is denoted by b and the sum of the width of all of the blades is denoted by B. K in the diagram represents the total resultant force on the blade elements and k the resultant pressure coefficient, so that $K = \rho/g\ (kSW^2)$, but the area of the element of all of the blades is $B\partial R$, so that

$$K = \rho/g\ (kB\partial RW^2)$$

$$W = \tfrac{1}{2}v[\cos(\Phi+\beta)\ /\ \sin\Phi]$$

$$K = \rho/g[kB\partial R(\tfrac{1}{2}v)^2\{\cos^2(\Phi+\beta)\ /\ \sin^2\Phi\}] \qquad (1)$$

From the impact theory, however, $K = v\partial M$. Since ∂M is the mass of air flowing through the annulus per unit of time

$$\partial M = \rho/g \cdot \tfrac{1}{2}v\cos\ (\Phi+\beta)\partial A$$

the inflow velocity being taken as one-half the outflow. $\partial A = 2\pi R \cdot \partial R$; hence

[2] General Theory of Blade Screws by George de Bothezat, National Advisory Committee for Aeronautics Report No. 29, 1918.

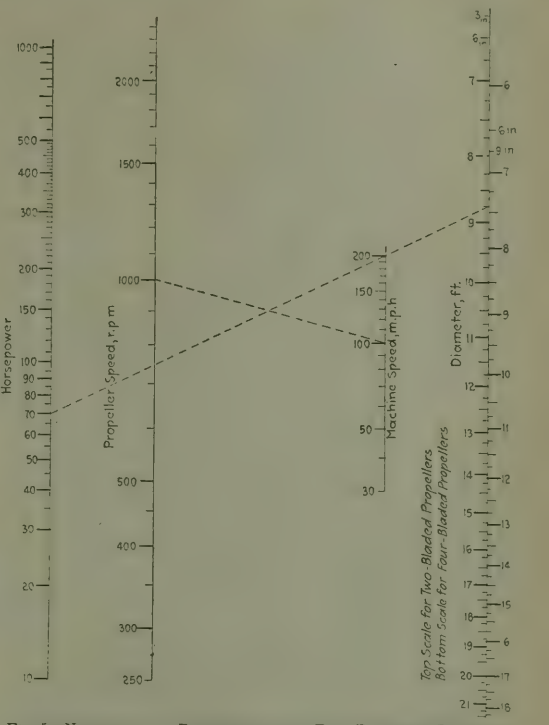


FIG. 5—NOMOGRAM FOR DETERMINING THE BEST PROPELLER DIAMETER FOR A GIVEN COMBINATION OF HORSEPOWER AND ENGINE AND PLANE SPEEDS AT THE GROUND

$$\partial M = \rho/g \cdot \tfrac{1}{2}v\cos\ (\Phi+\beta) \cdot 2\pi R \cdot \partial R$$

and

$$K = \rho/g[\cos\ (\Phi+\beta) \cdot 2\pi R\partial R \cdot v]$$
$$= \rho/g\ (\tfrac{1}{2}v)^2[\cos(\Phi+\beta) \cdot 2\pi R\partial R \qquad (2)$$

Equating (1) and (2) and simplifying we get

$$kB[\cos\ (\Phi+\beta)\ /\ 2\sin^2\Phi] = 2\pi R$$

or

$$k(B\ /\ 2\pi R) = 2\sin^2\Phi\ /\ \cos\ (\Phi+\beta)$$

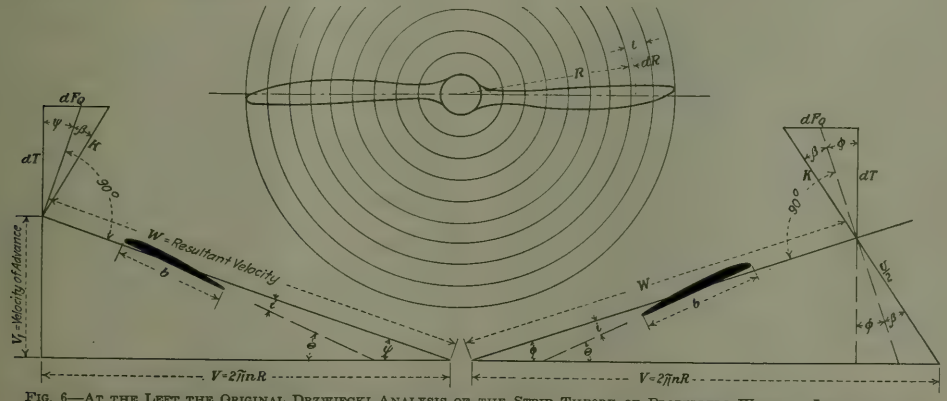


FIG. 6—AT THE LEFT THE ORIGINAL DRZEWIECKI ANALYSIS OF THE STRIP THEORY OF PROPELLERS WITHOUT INFLOW, IN THE CENTER AN ILLUSTRATION OF THE STRIP THEORY OF PROPELLERS AND AT THE RIGHT AN ANALYSIS OF THE VELOCITIES AND FORCES ACTING ON AN ELEMENT OF THE PROPELLER BLADE ROTATING AT A FIXED POINT

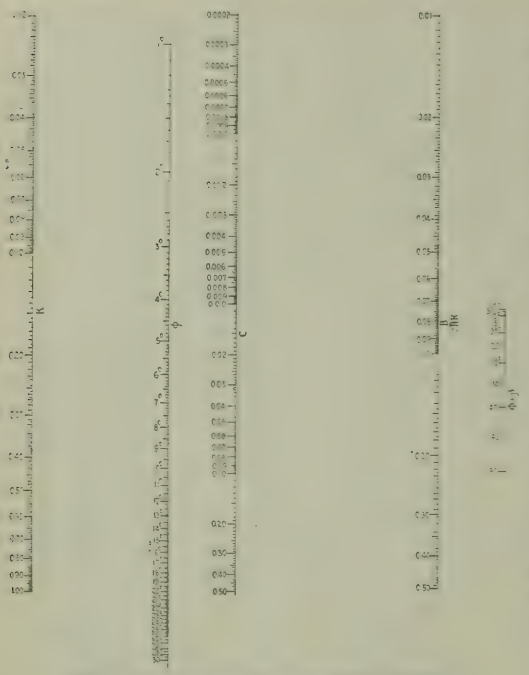


FIG. 7—NOMOGRAM FOR COMPUTING STATIC THRUST

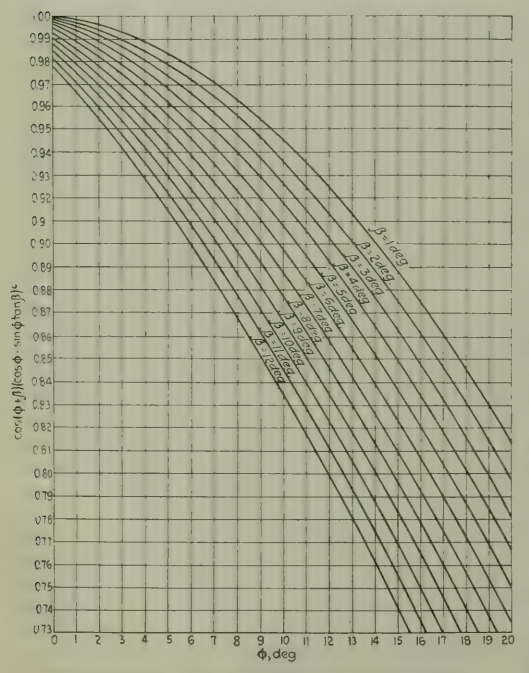


FIG. 8—GRAPHIC CHART FOR DETERMINING STATIC THRUST

This equation permits of a ready solution for ϕ when $B/2\pi R$, k and β are known. The equation is represented graphically by the nomograms in Fig. 7. To find ϕ, connect k and $B/2\pi R$ and find the product on the scale C. Rotate the straight-edge about this point until the value of ϕ, read on the ϕ scale, plus the known value of β, equals $\phi+\beta$, read on the $\phi+\beta$ scale. It can be shown that

$$W = 2\pi nR\ (\cos\Phi - \sin\Phi\tan\beta)$$

so that

$$K = \rho/g\,(K_1 B\partial R) \times (2\pi nR)^2 \times (\cos\Phi - \sin\Phi\tan\beta)^2$$

and since

$$\partial t = K\cos(\Phi+\beta) = \rho/g\,(kB)\times(2\pi nR)^2\times(\cos\Phi - \sin\Phi\tan\beta)^2\cos(\Phi+\beta)\,\partial R$$

or

$$\partial T = \rho/g[K(B/2\pi R)\times(2\pi)^3\times N^2R^2\times(\cos\Phi - \sin\Phi\tan\beta)^2\cos(\Phi+\beta)\,\partial R$$

This can be written

$$\frac{\partial T}{\partial R} = \rho/g\left[\frac{\pi^3}{D_1}\cdot k\cdot\frac{B}{2\pi R}\cdot\left(\frac{R}{R_1}\right)^3\cdot(\cos\Phi - \sin\Phi\tan\beta)^2\cos(\Phi+\beta)\right]n^2D_1^4$$

If the quantity in the brackets be plotted against R/R_1 and integrated, we shall evidently find the value of the quantity T_c in the formula

$$T = \rho/g\,T_c n^2 D_1^4$$

To simplify the calculation for thrust the expression $\cos(\phi+\beta)\ (\cos\phi - \sin\phi\tan\beta)^2$ has been shown graphically in Fig. 8 for various values of ϕ and β.

The torque coefficient Q_c can be computed in a similar way. The value of the ratio of thrust to torque takes a very simple form

$$\frac{\partial T}{\partial Q} = \frac{1}{R\tan(\Phi+\beta)}$$

In Fig. 1 the ratio of the thrust to the torque force F_q has been worked out for various values of $B/2\pi R$ and various angles of attack for a given airfoil section. It can be seen that the optimum angles for the best value of $\frac{\partial T}{\partial F_q}$ is always lower than the angle of maximum L/D and approaches the angle as a limit as $B/2\pi R$ approaches zero.

At the same time the value $\frac{\partial T}{\partial F_a}$ approaches L/D as limit as $B/2\pi R$ approaches zero.

BEST DIAMETER FOR HIGHEST THRUST

The characteristic equation for thrust is

$$T = \rho/g\,T_c n^2 D^4$$

The corresponding equation for power is

$$P = \rho/g\,P_c n^3 D^5$$

Hence the thrust per unit of power is

$$T/P = [\rho/g\,(T_c n^2 D^4)]\div[\rho/g\,(P_c n^3 D^5)] = T_c/P_c nD$$

This is evidently a maximum when nD has its minimum value.

$$P = P_c n^3 D^5 = P_c (nD)^3 D^2$$

$$nD = (P/P_c)^{\frac{1}{3}} D^{-\frac{2}{3}}$$

Holding P constant and differentiating

$$\frac{\partial(nD)}{\partial D} = -\tfrac{2}{3}\left(\frac{P}{P_c}\right)^{\frac{1}{3}}\cdot D^{-\frac{5}{3}} = 0$$

and

$$\frac{\partial^2(nD)}{(\partial D)^2} = \tfrac{10}{9}\left(\frac{P}{P_c}\right)^{\frac{1}{3}}\cdot D^{-\frac{8}{3}}$$

Hence the condition for a maximum value of thrust in that the diameter should approach infinity as a limit.

For purposes of lifting, however, the formula for thrust must be modified as the weight of the propeller must be subtracted. In general the selection of proper diameter and speed of revolution will be a question of engineering judgment rather than of calculation, since structural features of the wings, landing gear, etc., must be taken into account. The calculation will serve only to show us what thrust can be realized and what revolutions are required when a maximum diameter has been chosen and the power available is known.

The object in introducing the above discusison is to show that there is no difficulty in obtaining sufficient static thrust for hovering with present aircraft, provided the powerplant and the propeller are modified to suit the conditions. The type of propeller described above would be of entirely too low pitch for level flight, however. To meet both conditions successfully an adjustable-pitch propeller will be necessary. The tests on the Hart adjustable-pitch propeller, whose development has been carried out under my supervision, have shown that we are now in a position to build satisfactory adjustable-pitch propellers without the introduction of any considerable increase of weight.

If this method is extended to apply to forward flight conditions, the formula for ϕ becomes

$$\frac{2\sin^2\Phi}{\cos(\Phi-\beta)} = k\cdot\frac{B}{2\pi R}\left[\frac{\tan\Psi}{\tan\Phi-\tan\Psi}+\frac{\tan(\Phi+\beta)\tan\Phi\tan\Psi}{\tan\Phi-\tan\Psi}+1\right]$$

Fig. 9 shows a nomogram for the solution of the above quantities to be used in connection with Fig. 10. Thus, knowing k, β, ψ, we can find ϕ and knowing ϕ compute the thrust and torque coefficients as before.

The work absorbed by the element is evidently $\partial F \cdot 2\pi nR$, while the work delivered is $\partial T \cdot V_1$. Hence the efficiency is given by the equation

$$e = \partial T\cdot V_1/\partial F_Q\cdot 2\pi nR = \tan\Psi/\tan(\Phi+\beta)$$

It should be noted that the efficiency found by this method is always lower than the efficiency obtained by the simple Drzwiecki method illustrated in the lower left corner of Fig. 6 where

$$e = \tan\Psi/\tan(\Psi+\beta)$$

Micarta and Steel Propellers

A material which has shown great promise for use in propellers is manufactured by the Westinghouse Electric & Mfg. Co. under the name of Micarta. This material is made up of laminations or sheets of paper or fabric impregnated with Bakelite as a binder. In the case of the propellers the sheets are cut out in a form similar to the laminations of the wooden propellers, laid in a mold conforming to the exact shape of the finished propeller and heated for 3 hr. at a temperature of 350 deg. fahr., and having a pressure of about 1000 lb. per sq. in. The mold is provided with a stripping feature which greatly facilitates removing the finished blades.

Propellers made in this way are finished complete when molded, and are bored for a hub in such a way as to correct any small inequalities in the density of the material which might lead to imperfect balance. The type of hub used is a cylindrical sleeve provided with four keys, a small flange on one end and a nut and loose flange on the other. The density of Micarta is about 1.35, so that the material itself is considerably heavier than wood. The additional weight is usually just about offset by the saving in weight of the hub construction. Two physical

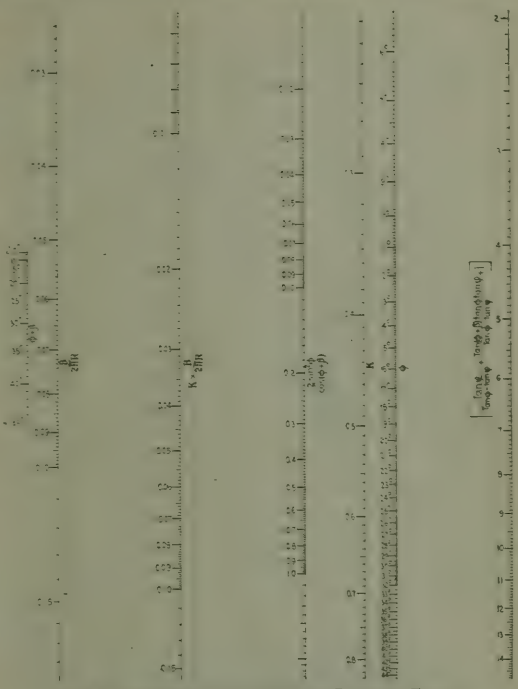


Fig. 9—Nomogram for Computing Dynamic Thrust

properties of Micarta which make it especially suitable for propeller construction are its great flexibility and the fact that it does not readily take up harmonic vibration. It has the additional advantage over wooden propellers that there is no tendency to split, and the grain can be put in any desired direction. Since the crushing strength is very high it is possible to drive direct by keys, without resorting to the usual construction of flanges and bolts.

Where micarta propellers are used it appears that it will be possible to dispense with the metal hub altogether,

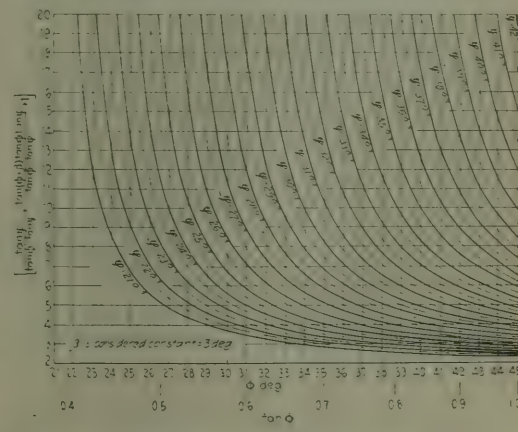


Fig. 10—Graphic Chart for Computing Dynamic Thrust

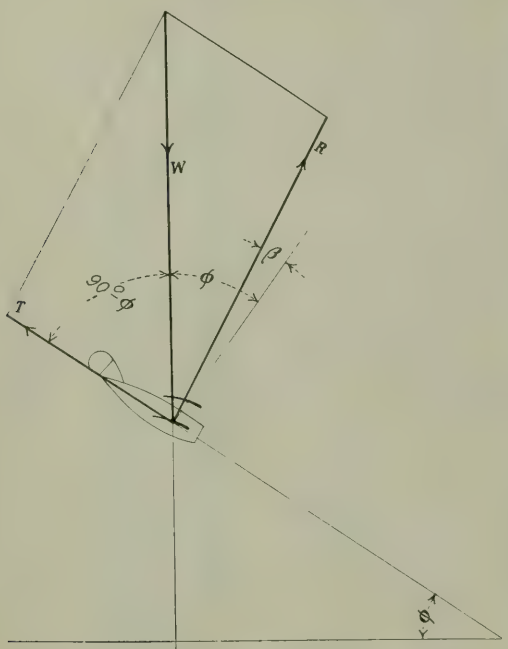


FIG. 11—ANALYSIS OF THE FORCES ACTING ON AN AIRPLANE WHEN GLIDING WITH REVERSE THRUST

provided the single key used at present as in the S.A.E. Standard shaft-end is replaced by four keys. The material is especially well suited to adjustable-pitch and reversible propellers, in that it permits of very simple and light connection between the blade and the hub of the propeller. It is anticipated that the reversible propeller with Micarta blades will be considerably lighter and more durable than the same type propeller with wooden blades, and will probably be less expensive.

At present a number of Micarta propellers are in service on the Liberty engine with very excellent results. I have designed a Micarta propeller for use on the Liberty engine with the USD-9 airplane. This propeller is laid out in such a way that the centrifugal moment produces a torsional effect tending to increase the pitch, while the thrust load produces a torsional moment tending to decrease the pitch. Thus, when the propeller is turning at a comparatively slow speed and at relatively high thrust, with the airplane standing still, the pitch of the propeller is considerably lower than at top speed when the engine revolutions have increased somewhat, and the thrust has decreased considerably. This feature gives a smaller change in revolution with the engine at full throttle, between the condition at fixed point and the top-speed condition, than is customary with most propellers. For example, most propellers on the Liberty engine show a gain of about 18 per cent between the condition at fixed point and top speed, while the Micarta propeller for this job showed an increase in the number of revolutions of only about 10 per cent. On the USD-9 this propeller showed a slightly better climb and top speed than the wooden propeller for the same job, although turning about 150 revolutions slower at top speed. Thus the radius of action on this plane was greatly improved. A propeller of the same design was used by Major Schroeder in his record-breaking altitude flight. The feature of the increased pitch with an increased number of revolutions and a decrease in the thrust is particularly valuable in connection with the supercharger which was used on this flight, as it gives very simple and direct automatic control of pitch.

The Micarta propellers are extremely durable, being very little affected by grass, sand, small stones, rain, etc. This development appears to have very great possibilities for improvement of propellers.

An enormous amount of research and experimental work has been done throughout the world on steel propellers with little success, as very few, if any, steel propellers are in actual service at the present time. The efforts have been concentrated for the most part along three general lines:

(1) A blade made of two formed sheets welded together along the edges
(2) A blade formed from a tube without welding at the edges except at the tips
(3) Solid steel blade

Under the first classification an interesting development is the Leitner steel propeller designed by H. C. Watts, formerly of the British Air Board. This type of propeller is made up of several sheets of thin material fastened together by riveting, or in some cases by spot welding. The object of the lamination of the material is to avoid harmonic vibration by attaching several pieces having different periods. A number of these propellers

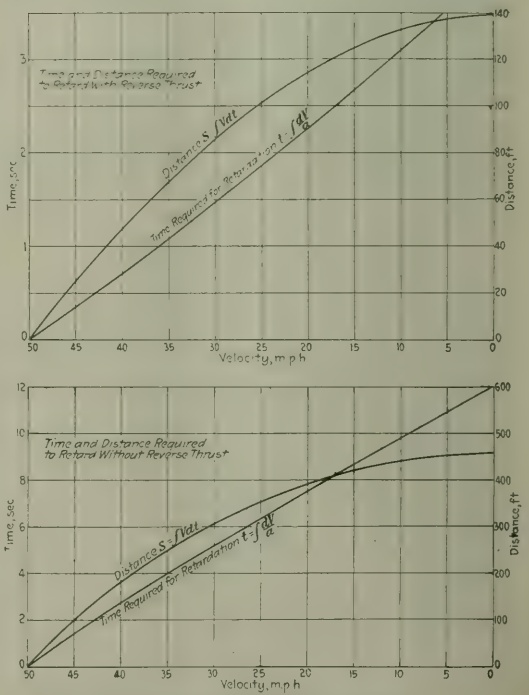

Time and Distance Required to Retard With Reverse Thrust
Distance $S = \frac{1}{2}Vdt$
Time Required for Retardation $t = \frac{V}{a}$
Time, sec
Distance, ft
Velocity, m p h
Time and Distance Required to Retard Without Reverse Thrust
Distance $S = \frac{1}{2}Vdt$
Time Required for Retardation $t = \frac{V}{a}$
Time, sec
Distance, ft
Velocity, m p h

FIG. 12—TIME AND DISTANCE REQUIRED TO RETARD AN AIRPLANE WITH AND WITHOUT REVERSE THRUST

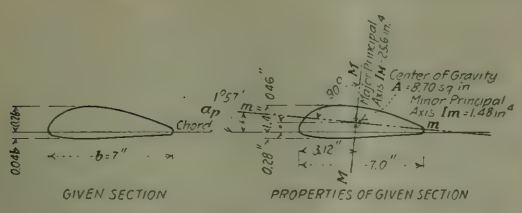


FIG. 13—INSTRUCTION SHEET GIVING THE SECTION PROPERTIES FOR STANDARD AIRFOILS FOR PROPELLERS

It is required to find the properties of a standard airfoil section whose blade width is 7 in. with upper and lower camber ratios of 0.20 and 0.04 respectively. The first step is to find the properties of a similar airfoil with a 10-in blade width, and then by the application of the reduction factors obtain the properties for a 7-in. blade width.

REDUCTION TABLE

Item	Symbol	Value for 10-in. Blade Width	Reduction Factor	Value for 7-in. Blade Width
Blade Width, in.	b	10.00	0.7	7.00
Maximum Upper Camber, in.	h_u	2.00	0.7	1.40
Maximum Lower Camber, in.	h_l	0.40	0.7	0.28
Center of Gravity from Left End Measured along Chord, in.	b_c	4.46	0.7	3.12
Center of Gravity above Chord, in.	h_c	0.66	0.7	0.46
Area, sq. in.	A	17.75	$(0.7)^2$	8.70
Angle between Minor Principal Axis and Chord, deg. mm.	a_p	1-57	1.0	1-57
Moment of Inertia about Minor Principal Axis, (in.)^4	I_m	6.17	$(0.7)^4$	1.48
Moment of Inertia about Major Principal Axis, (in.)^4	I_{1f}	106.30	$(0.7)^4$	25.60

It stood a remarkable overload test; the cast-steel hub giving way at 2400 r.p.m. The blade, which is 11½ ft. in diameter, was designed for 200 hp., and at this speed was absorbing about 800 hp. This type of construction appears to have some interesting possibilities, particularly with reversible propellers.

The steel-propeller experiments have demonstrated that the most important consideration in the construction of steel propellers is the degree of flexibility. As is explained under the head of propeller stresses, the centrifugal force always provides a restoring moment in a properly designed flexible propeller. In the design of the steel propeller it is necessary to provide sufficient flexibility to obtain this restoring moment without introducing any very great stresses in the material. At the same time, too great flexibility must be avoided; otherwise the result would be too low a period of oscillation, resulting in violent fluttering of the blades. It is my belief, based on a very wide experience in designing and testing steel propellers, that this feature of flexibility is a most vital one in connection with steel propeller design, and that to non-comform with this requirement has been the cause of most of the failures.

In addition to the above-mentioned steel propellers, the Army Air Service has tested a very large number of interesting designs. Moreover, a great many different types of steel propellers have been tested by the Italians, French, Germans and British. The steel propeller experiments have now reached a point where it seems that something very good will be produced in the near future.

ADJUSTABLE-PITCH AND REVERSIBLE PROPELLERS

Considerable attention has been given adjustable-pitch propellers by experimenters in various countries. A

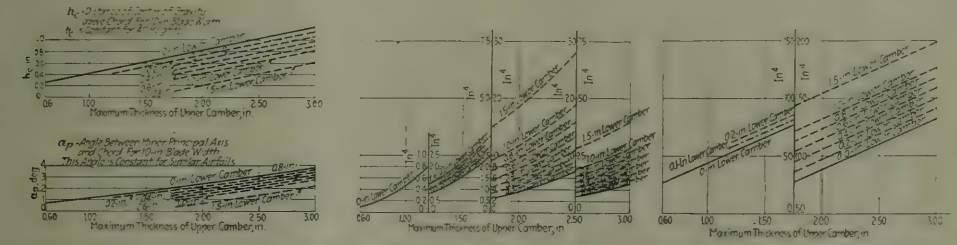

Maximum Thickness of Upper Camber, in.
Maximum Thickness of Upper Camber, in.
Maximum Thickness of Upper Camber, in.
Maximum Thickness of Upper Camber, in.

FIG. 14—CHARTS GIVING THE VALUES FOR THE DISTANCE OF THE CENTER OF GRAVITY ABOVE THE CHORD THE ANGLE BETWEEN THE MAJOR PRINCIPAL AXIS AND THE CHORD AND THE MOMENTS OF INERTIA ABOUT THE MINOR AND MAJOR PRINCIPAL AXES FOR A 10-IN. BLADE WIDTH

are said to have been built for small engines and the builders make large claims for its effectiveness.

The most advanced construction of the tubular type is a reversible propeller built by the Standard Steel Propeller Co. of Pittsburgh. On account of the hollow steel construction it is possible to put all the reversing mechanism on the inside of the blade, giving a very clean appearance to the design. In this case the tubing is swaged down and reamed inside and turned outside to give a thickness tapering toward the tip, as well as a diameter tapering toward the tip. After machining, the tubes are brought to a red heat and pressed to shape in a mold. The material used is a nickel uranium steel which shows some very interesting properties for aircraft purposes.

I designed a solid steel propeller to test out the possibilities of the third type of construction. As was anticipated, this showed a terrific flutter at low speeds on account of the extreme flexibility but ran very smoothly

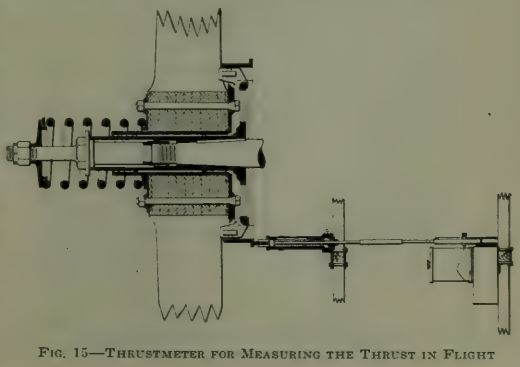


FIG. 15—THRUSTMETER FOR MEASURING THE THRUST IN FLIGHT

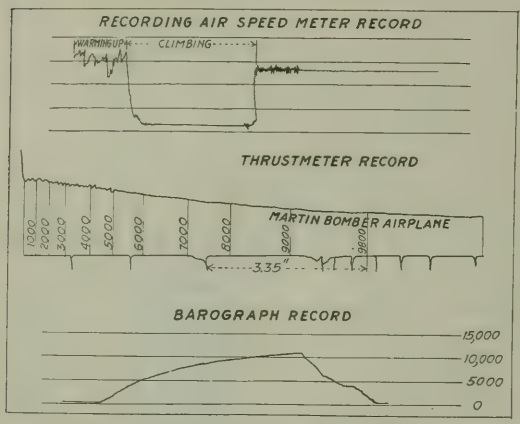
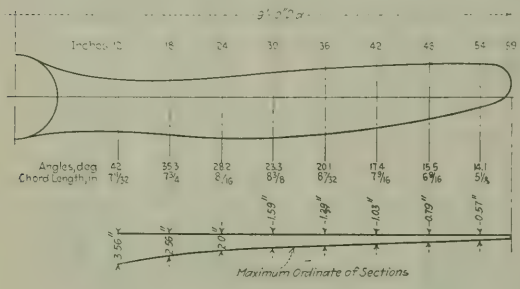


FIG. 16—RECORDS GIVEN BY AN AIR SPEED METER, THE THRUSTMETER AND A BAROGRAPH OF AN AIRPLANE FLIGHT

type invented by Professor Reissuer, in Germany, is described briefly in *Technische Berichte*, Vol. III, Section 5. A second type made by Levasseur, in France, has been exhibited at several shows. An adjustable-pitch propeller was produced by the Royal Aircraft Factory in England. So far as I am aware, none of these propellers is in actual service, and from the information available as to their construction it does not appear that the factor of safety would satisfy our requirements.



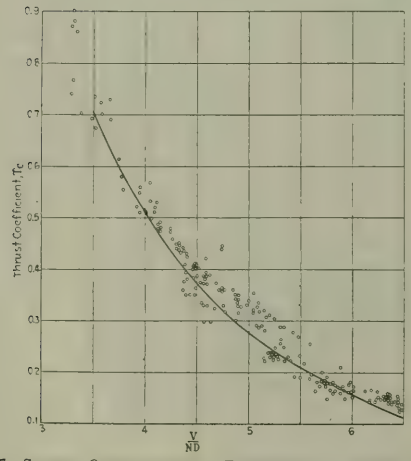


FIG. 17—SECTION ORDINATES FOR A PROPELLER AND UNDERNEATH A COMPARISON OF THE THRUST COEFFICIENTS OBTAINED IN WIND-TUNNEL AND THRUSTMETER TESTS, THE POINTS BEING GIVEN BY THE THRUSTMETER TEST AND THE CURVE BY THE WIND-TUNNEL TEST

It is no secret that the Army Air Service has had considerable success with the Hart adjustable-pitch and reversible propellers, but it is impossible for military reasons to make public any details of its construction at the present time. This propeller was invented by Seth Hart of Los Angeles, Cal., and several experimental propellers were built at his expense in California, and a number of flight tests were made there by several pilots. Among the pilots who made the first flights were Earl Dougherty and Lieutenant Mairesse of the French Army. The California flights gave such promise of success that Mr. Hart determined to bring the invention before the Government's Airplane Engineering Department at McCook Field.

The first test given the propeller was a destructive whirling test made to insure its safety for flying purposes. The results of this were so encouraging that the propeller with a few modifications was made ready for flying in a JN-4H airplane. All of the flights with this propeller were made by Caleb Bragg; a very thorough series of tests covering about 8 hr. in the air was made by him. The principal advantages brought out by these tests were that the variable-pitch showed an increase in rate of climb of about 40 per cent as compared with the fixed-pitch propeller, an improvement in ceiling of about 20 per cent and a great gain in the time required for take-off. While it was realized that a considerable length of time would be required to get this propeller ready for production, it was decided to carry on its development as fast as possible without interfering with current production.

The tests have already gone far enough to demonstrate that it is practicable to land an airplane equipped with this propeller on a roof of moderate size and, with some of the modern airplanes, to take-off again. This is possible with existing airplanes designed for military service. With specially designed airplanes the propeller opens the way for a development that should prove of great value to commercial aeronautics. Of course, the first application of adjustable-pitch and reversible propellers ought to be as military and naval equipment. The advantages to the Navy of making possible landings on ships fitted with landing platforms, and to the Army in permitting landings in very small areas, are self evident. Also, the use of the reverse in the air gives the pilot an opportunity for a number of new maneuvers that ought to be very valuable in battle tactics. Reversible propellers in dirigible balloons are well recognized as an aid in maneuvering and in stopping. They are considered essential in ships of very large size. The adjustable-pitch feature of the Hart propellers, which is always combined with the reversible feature, gives a more rapid take-off, a better rate of climb, a higher ceiling, more efficient operation at cruising speed, leading to a greater radius of action, combined with an efficiency at top speed equal to that of the ordinary wooden propeller.

It has been recognized by all those in different countries experimenting with superchargers that the efficient operation of this device is contingent on the development of an adjustable-pitch propeller. This applies with particular force to equipment designed to operate at heights greater than 20,000 ft. The conventional propeller, if designed to operate at 20,000 ft., will turn altogether too

slowly near the ground, and is designed to operate near the ground it will turn altogether too fast at a great altitude. This condition can be met only by the adjustable-pitch propeller, which will permit the engine to operate at a uniform rate at all altitudes. The effect of adjustable pitch on the performance of airplanes with the conventional type of powerplant was described in a paper which I presented before this Society and which was published in THE JOURNAL[2].

I shall not go into the method of computing performance in detail in this paper. In general, there is a great improvement in the time and distance required for leaving the ground when the adjustable-pitch propeller is substituted for the fixed pitch. At the same time an improvement in the rate of climb, ceiling and cruising radius is possible without any sacrifice of top speed. It may be well to call attention to the method of calculating the distance required to stop a plane equipped with reversible propellers. In this discussion the following notation is employed.

W = the weight of the airplane
V = the speed of the airplane
T = the reverse thrust
t = the number of seconds elapsing after the propeller is reversed
s = the distance covered by the airplane after the propeller is reversed
γ = the value of L/D of the wings corresponding
R = the parasite resistance at unit velocity

The retarding forces are

(1) The reverse thrust or T
(2) The wing drag or W/γ
(3) The parasite resistance or RV^2

The rate of retardation can be computed from the formula $F = Ma$

$$\partial^2 s = (gt/W + g/\gamma + gRV^2/W)\partial t^2$$

$$s = \int_o^t \int_o^t (gt/W + g/\gamma + gRV^2/W)\partial t^2$$

This expression gives the distance which the airplane has traveled during a time t after the reverse is applied.

In determining the effect of reverse thrust on the gliding angle

Φ = the angle of descent (See Fig. 11)
β = the angle between the normal to the path of the airplane and the resultant pressure
$= \tan^{-1} D/L$
$= \cot^{-1} \gamma$

Assuming the propeller thrust to be applied parallel to the path

$$W = T \sin \Phi + R (\cos \Phi \cos \beta + \sin \Phi \sin \beta)$$

The following equation connects β, R T and W

$$W = V [T^2 + R^2 - 2RT \cos (90 + \beta)]$$

As an example of the effect of the reverse thrust on the gliding angle, the following can be cited from a practical case. Assume $T = 1000$ lb., $W = 2000$ lb., and $\beta = \tan^{-1} 1/8 = 7$ deg. 7 min. Then the gliding angle ϕ by the above becomes equal to 36 deg. 50 min. Evidently by varying the reverse thrust any desired gliding angle can be obtained. This feature will, of course, prove valuable in entering a confined space but may require much skill in manipulation.

The forces brought into play in landing are

(1) The parasite resistance of the body
(2) The wing-drag
(3) The friction of the wheels and the tail-skid
(4) The reverse thrust in the case of a reversible propeller

[2] See THE JOURNAL, August, 1918, p. 132.

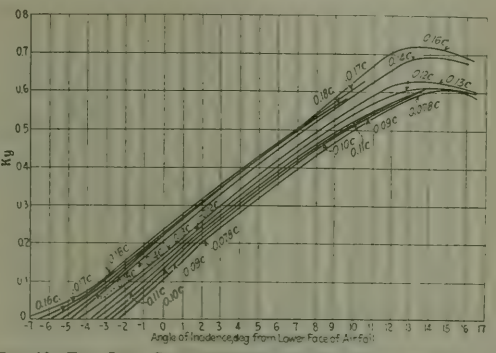


FIG. 18—THE LIFT CHARACTERISTICS OF THE PROPELLER SECTION SHOWN IN FIG. 2

The parasite resistance and wing-drag may be grouped together if we assume the wings to be set at the stalling angle. In this case resistance, parasite and wing drag will be proportional to the square of the speed. The sum of the two can then be written RV^2.

The coefficient of friction on the wheels can be taken as f and the load on the wheels will be the weight minus the lift, or $(W - K_y AV^2)$ where K_y is the maximum value. The frictional resistance will be $f(W - K_y AV^2)$.

The total retarding force in the case of an airplane without reverse thrust will be

$$RV^2 + f(W - K_y AV^2) = W/g \times \text{the retardation}$$

The formula for the distance required to stop without reverse thrust is

$$s + c_2 = -[W/g(R - fK_y A)] \log \{\sec[(t + c_1) g(R - fK_y A)^{1/2}/W]\}$$

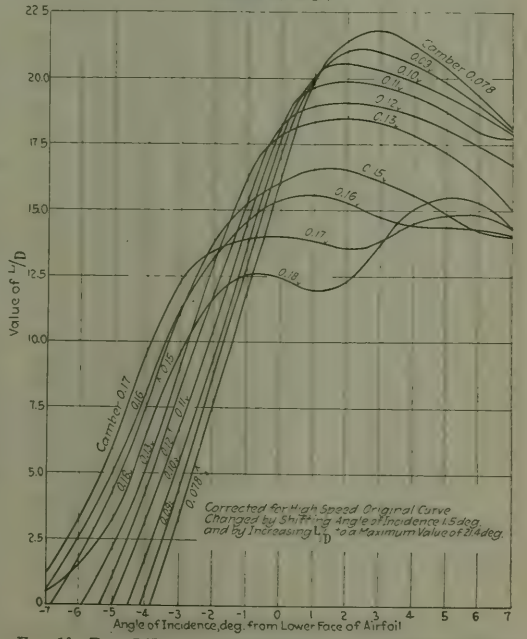

Value of L/D
Angle of Incidence, deg. from Lower Face of Airfoil
Camber 0.078
Corrected for High Speed, Original Curve Changed by Shifting Angle of Incidence 1.5 deg. and by Increasing L/D to a Maximum Value of 21 deg.

FIG. 19—THE L/D CHARACTERISTICS OF THE PROPELLER SECTION SHOWN IN FIG. 2

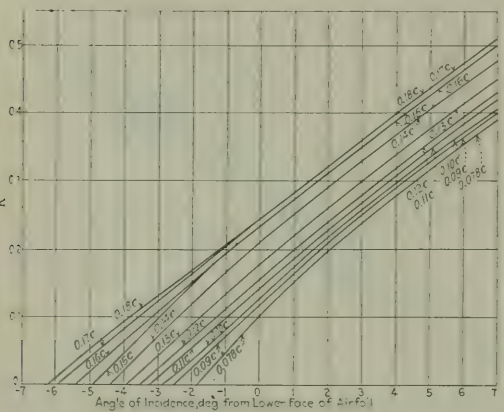


FIG. 20—CURVES GIVING THE TOTAL RESISTANCE COEFFICIENT FOR THE PROPELLER SECTION SHOWN IN FIG. 2

In case reverse thrust is applied, the expression for the distance traveled becomes

$$s = g/W \int_o^t \int_o^t [RV^2 + f(W - K_y A V^2) - T] \partial t$$

Since the thrust is variable and cannot be expressed readily in terms of v or t, it is necessary to resort to a graphical method.

The following data can be assumed to constitute an example of landing conditions:

Weight of airplane complete = 2075 lb.
Area of supporting surface = 250.5 sq. ft.
The parasite resistance is equal to 0.01127 V^2
The maximum value of K_y in lb. m.p.h. units = 0.00265
The corresponding value of L/D is 7.5

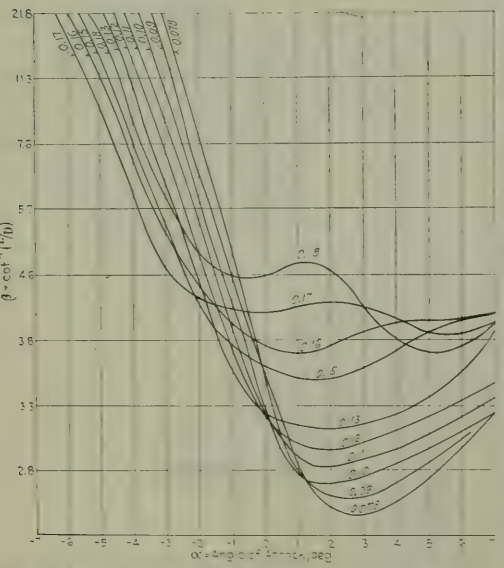


FIG. 21—ANGLE BETWEEN THE NORMAL TO THE PATH AND THE DIRECTION OF THE RESULTANT PRESSURE FOR AIRFOILS OF VARIOUS THICKNESSES

The coefficient of friction between the wheels and tail-skid and the earth is 0.2

The corresponding time and distance required to stop are shown in the two sections of Fig. 12.

PROPELLER STRESSES

The question of propeller stresses has received considerable attention during the last few years and the following are well recognized and computed:

(1) The direct tension due to centrifugal force
(2) The bending moments in the thrust and torque plane due to centrifugal force
(3) The bending moments in the thrust and torque plane due to air pressure

In addition to the above, however, very important stresses are introduced by the torsion due to the air pressure and by the torsion due to the centrifugal force.

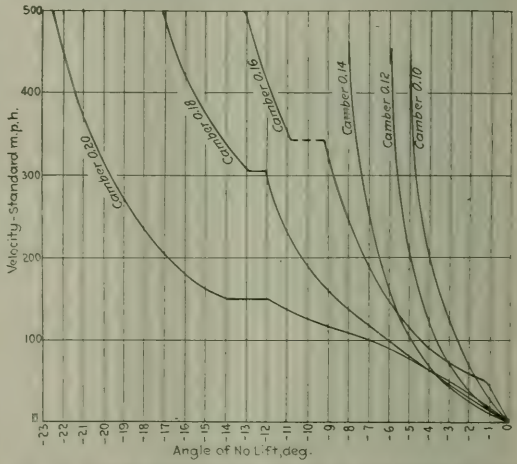


FIG. 22—CURVES SHOWING THE CHANGE IN THE ANGLE OF ZERO LIFT AS THE SPEED INCREASES

In computing stresses it is convenient to start out with the centrifugal force at various stations along the blade. This centrifugal force is computed from the cross-sectional area at the radius of the element under consideration. Applying this formula, the centrifugal force is equal to 1.227 Δ A L N^2 R, the value of Δ being taken as the density of the material. From these values the centrifugal force acting on each section can be found and, knowing the relative location of the various sections, the bending moments due to centrifugal force can be computed. The thrust and torque are computed from the characteristics of the airfoil sections and the resulting bending moments found.

If the section properties of the various cross-sections of the propeller are known, the stresses can be computed by the usual method of analytical mechanics. The section properties for the series of airfoils referred to in this paper are tabulated in convenient form in Figs. 2, 13 and 14, and can be worked out very rapidly for a propeller section of given camber ratio and width from Fig. 13 by following the instructions given underneath the illustration. For most purposes these section properties will apply to airfoils of somewhat different shape with sufficient precision, provided the camber ratio is known.

In making a static stress analysis of a propeller it should be borne in mind that no action of the deflection of the blade is taken into account. This deflection nearly always results in a considerable reduction of the stress on account of the restoring moments introduced by the centrifugal force. The static stress analysis gives a fairly good comparison of strength values of propellers, provided the shape of the blade is such that it is free from flutter.

Propeller Testing

Propeller tests are usually carried out in four ways; (*a*) flight tests to determine the efficiency and adaptability of the propeller, (*b*) wind-tunnel tests to determine the efficiency and adaptability of the propeller by tests on a small model, (*c*) whirling tests to determine the factor of safety and structural features of full-size propellers and (*d*) tests made on propeller materials and processes of manufacture. Flight tests of propellers have been rather difficult owing to the many sources of error which may reduce the precision and to the lack of suitable instruments. At the present time, however, there are a number of instruments available and under development which ought to make these tests more satisfactory. In addition to the altimeter, barograph, chronometric tachometer, recording and indicating air-speed meters and thermometers which are used in airplane testing, it is desirable to have thrust and torque meters and a satisfactory means for measuring the slip and race velocities when testing propellers. I shall attempt to give a very brief description of some of these special instruments which have been developed in the last few years.

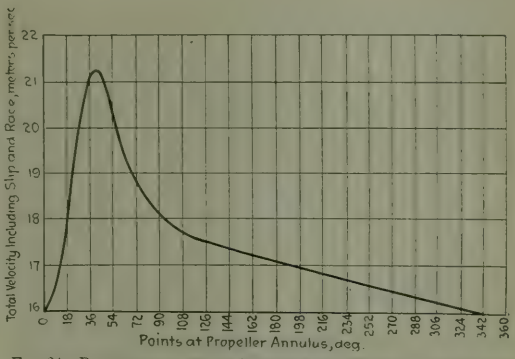


Fig. 21—Distribution of the Pressure and Velocity around the Propeller Annulus at a Radius of 30 Cm. (11.81 In.)

An instrument which has the very desirable feature of giving simultaneous readings of thrust and torque is the dynamometer hub developed by Dr. Bendemann and tested by the Germans on a Rumpler C-2. The thrust and torque reactions are taken up by pistons working in cylinders filled with oil and the resulting oil pressure is recorded on a drum located in the cockpit. This pressure is led from the cylinders to an extension of the crankshaft and thence through oil-tight grooved rings to a series of tubes leading to the cockpit. It is necessary to carry these tubes all the way around the propeller and the construction is rather clumsy in this respect. It appears that the construction has also been

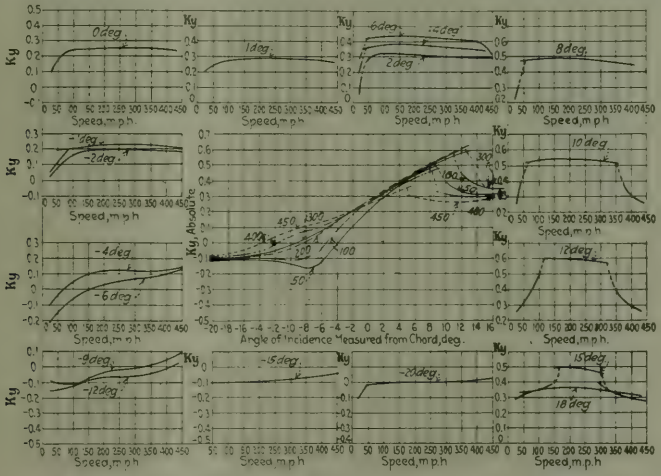


Fig. 23—Curves Showing a Decrease in the Lift Coefficient and a Simultaneous Increase in the Drag Coefficient Where the Type of Air-Flow Changes

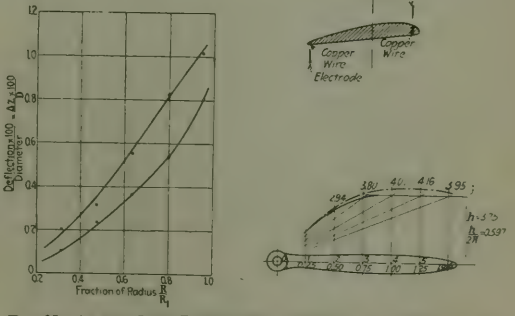


Fig. 25—At the Left Deflections Obtained in a Whirling Test on a German Propeller and in the Upper Right Corner the Method of Measuring the Deflections by Electric Contacts with the Change of Propeller Pitch Resulting from These Tests Underneath

hampered by the lack of first-class material. A fairly complete description of this instrument is given in Vol. III, Section 6, of the *Technische Berichte*. A second type of instrument used by the Royal Aircraft Factory in England is designed for measuring the thrust and makes use of an external cylindrical bushing attached to the engine shaft-end and, mounted on it, a propeller-hub with a cylindrical bore. This hub is driven by links and is free to move against a calibrated spring. The movement of this hub is traced by a follower roller on an external track and is read from an indicating dial in the cockpit.

Fig. 15 shows a thrustmeter designed by me which is believed to be much sturdier than either the British or German instruments and has the additional advantage that the spring can be calibrated on an ordinary testing machine. One of these instruments has had about 100 hr. in the air, including a flight from Dayton to Washington and return, without any serious wear. There is no appreciable vibration and the pilots do not even remove the instrument when the ship is wanted for cross-country flying. The recording drum in this case is mounted directly on the nose of the engine to avoid any errors introduced by the weaving of the airplane structure.

It is interesting to compare the thrust record shown in Fig. 16 with the air-speed and barograph records of the same flight. During the first 5000 ft. of this climb the air was bumpy or full of whirls. This is shown by the wavy lines in the records of thrust and air speed, and to a somewhat less degree in the barograph record. Above 5000 ft. smoother air was encountered and all three records show a smooth continuous line.

A comparison of the results obtained in the wind-tunnel with the full-scale results obtained from this instrument is interesting. The principal dimensions of the propeller design on which the tests were run are given in the upper part of Fig. 17. The full-scale propeller was 9 ft. 8 in. in diameter, and the wind-tunnel model was 3 ft. in diameter. The wind-tunnel tests were run at Leland Stanford University. A comparison of the thrust coefficients is shown in the lower portion of Fig. 17. The errors in the full-scale thrust coefficient are not thought to be due to lack of precision but rather to the difficulty of synchronizing the readings of the air-speed meter, tachometer, barograph, thermometers and thrustmeter. This emphasizes the desirability of recording all of these readings on the same chart. At the present time three different types of torque meter are being developed for airplane use, and it is anticipated that some very valuable propeller and engine data will be obtained when these are available.

The wind-tunnel tests, being less expensive, have been carried out on a rather comprehensive scale under two main divisions; (*a*) experiments with wing sections suitable for airscrew design and (*b*) tests of models for airscrews. The most valuable work under the former head has been done in England, while comprehensive tests of model screws have been carried out in England, France, Italy, Germany, Russia and the United States.

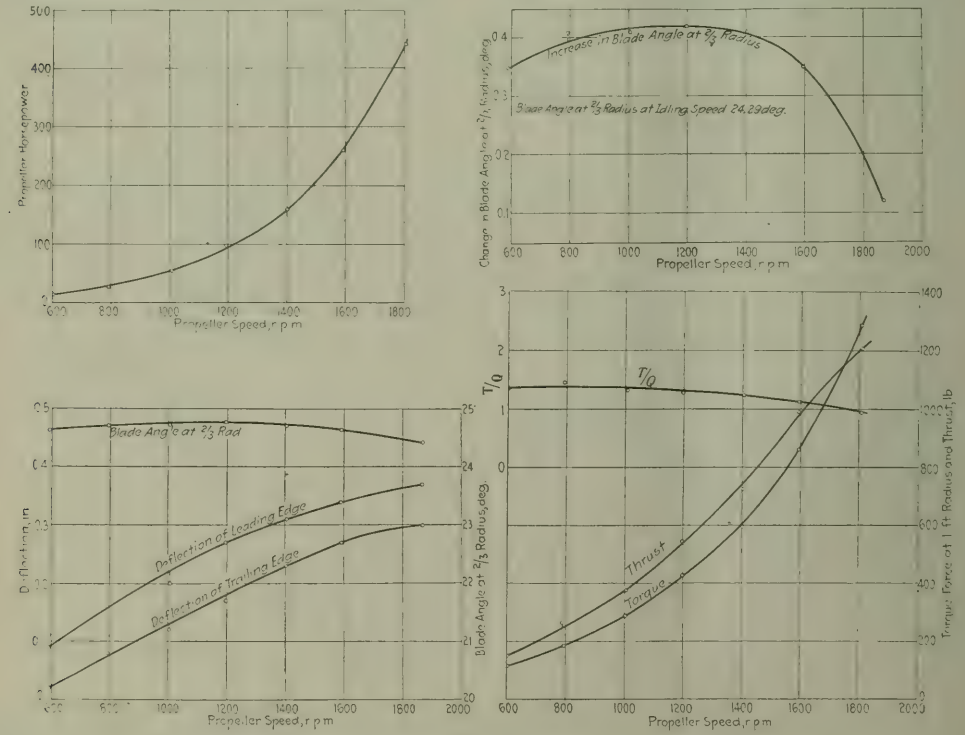

Propeller Horsepower
Propeller Speed, r p m
Increase in Blade Angle at 2/3 Radius
Blade Angle at 2/3 Radius at Idling Speed 24.29deg.
Change in Blade Angle at 2/3 Radius, deg.
Blade Angle at 2/3 Rad
Deflection of Leading Edge
Deflection of Trailing Edge
Blade Angle at 2/3 Radius, deg.
T/Q
Thrust
Torque
Torque Force at 1 Ft. Radius and Thrust, lb

Fig. 26—A Typical Set of Readings from a Propeller Test Made at McCook Field

TABLE 1—ACTUAL AND COMPARATIVE PROPERTIES OF VARIOUS WOODS AND OTHER AIRPLANE PROPELLER MATERIALS

Common and Botanical Name	Specific Gravity at 15 per cent Moisture Including Water	Shrinkage from Green to Oven-Dry Condition		Strength in Bending	Strength in Compres'n Parallel to Grain	Strength in Compres'n Perpend'l'r to Grain	Stiffness	Hardness		Shock Resisting Ability, lb.	Shearing Strength Parallel to Grain, lb per sq in.
		Radial, per cent	Tangential, per cent	Modulus of Rupture, per cent	Maximum Crushing Strength, lb. per sq. in.	Fiber Stress Elastic Limit, lb. per sq. in.	Modulus of Elasticity in Bending, lb. per sq. in.	Load Required to Imbed a 0.44-in. Ball for One-Half its Diameter, lb. per sq. in.			
Birch, yellow (Betula lutes)	0.63	6.9	8.9	13,200	7,040	[illegible]	1,800,000	980	19.0	1,622	
Cherry, black (Prunus serotina)	0.54	3.7	7.1	12,030	7,080	777	1,632,000	883	12.8	1,990	
Spruce, Sitka (Picea sitchensis)	0.39	4.5	7.4	8,240	5,200	570	1,480,000	490	6.4	1,165	
Maple, Oregon (Acer Macrophyllum)	0.51	3.7	7.1	11,080	6,480	970	1,370,000	830	8.7	1,660	
Oak, white (Quercus alba)	0.68	6.2	8.3	12,120	7,000	1,450	1,420,000	1,310	12.1	1,790	
Walnut, black (Juglans nigra)	0.59	5.2	7.1	14,230	8,600	1,051	1,770,000	1,195	14.6	1,822	
Poplar, yellow (Liriodendron tulipifera)	0.42	4.1	6.9	8,350	5,100	542	1,570,000	450	5.6	1,180	
Micarta	1.35	...	...	20,000	30,000	....	500,000	.....	....	2,000	
Mild Carbon Steel (Soft)	7.84	...	...	60,000	.....	....	29,000,000	.....	....	.....	
Alloy Steel (Heat-Treated)	7.84	...	...	100,000	.....	....	30,000,000	.....	....	.....	

It is impossible to do more than touch on this field of experiment in an article of this kind. A series of sections of British origin, which I have used to some extent with very good results, was shown in Fig. 2. The lift and L/D characteristics of these sections are shown in Figs. 18 and 19. The lift coefficients are the uncorrected values obtained at 30 m.p.h., while the L/D values are corrected for high speed. The same data are shown in Figs. 20 and 21, except that the total resistance coefficient is shown in one curve and the angle whose tangent is D/L is shown in the other. This is more convenient for studies of the inflow theory as the mathematics is considerably simplified in this way. I have recently completed some experiments, in conjunction with E. N. Fales, in the high-speed wind-tunnel which we have developed at McCook Field. It has been possible to carry these experiments up to a true air speed of 500 m.p.h. on account of the exceptionally uniform traverse of the air-flow in this tunnel and some new features of propeller airfoils have been brought to light. Of particular interest is the change of the angle of zero lift as the speed of the air increases. In Fig. 22 it will be seen that the angle of the chord at zero lift changes very slightly for thin airfoils, such as used in airplane wings, while the change in thick sections, such as are sometimes used in propellers, is enormous. Of further interest has been the visualization of the air-flow, of which numerous photographs have been obtained. In all of the airfoils tested we encountered at high speeds a critical velocity where the type of air-flow changes, the lift coefficient showing a sudden decrease and the drag coefficient a simultaneous increase as illustrated in Fig. 23. It is interesting to see the change in the air-flow at this critical speed as the flow changes in the same way for all the models.

One cannot give too much praise to the extremely careful and conscientious airfoil work done at the National Physical Laboratory in England. This work has formed the ground-work for much of the experimental work in propellers. Many valuable airfoil data have also been furnished by Eiffel, Costanzi, Prandtl and numerous other experimenters. Dr. Durand's monumental series of propeller tests is now so well known as to need no description. In addition to the published tests, many models of Air Service propellers have been tested at the Leland Stanford University through the cooperation of Dr. Durand and Professor Leslie. Of special interest among recent-model propeller tests is the series of tests of Eiffel with tandem propellers. M. Eiffel has shown that it is possible to have a tandem arrangement with very high-pitch propellers rotating in opposite directions, where the combination shows a higher efficiency than either propeller running alone owing to the absence of race rotation in a properly designed tandem combination. M. Drzwiecki has published the results of an extraordinarily interesting series of experiments wherein he obtained the instantaneous velocity distribution throughout an annulus of the propeller disc, and has shown the presence of a circulation about the propeller blade analogous to that known to exist about airplane wings. It appears that this series of experiments will make necessary a modification of the inflow theory which has become fairly well established during the last few years. (See Fig. 24.)

The facilities for making whirling tests of practical propeller designs, construction and materials have been fairly well developed in England, Germany and the United States; but, as far as I know, the French and Italians still depend on static tests. I am told that the French Section Technique was unable to obtain facilities of this kind during the war, owing to the scarcity of electrical machinery in France. The European whirling stands are all comparatively small; the largest so far as I know being capable of developing about 600 hp. The British have about three of these stands and make a very large number of tests. The Germans have a whirling stand for testing. In testing they have studied deflections in much the same way as we have studied them at McCook Field, taking the deflection of the leading and trailing edges and computing the change in angle. The upper view in Fig. 25 shows the test described by H. Dietzius in Vol. III, Section 2 of the *Technische Berichte*. The deflection measurements are obtained by means of electric contacts, but the exact method is not clearly described in this article. The results are typically the same as those observed in our propeller work, a greater deflection being noted on the leading edge, resulting in an increase of pitch.

The propeller-testing laboratory of the Air Service at McCook Field has a capacity of 1400 hp. for a short time, and is equipped with a bombproof and a special device, so that the propeller can be completely destroyed in testing without throwing any unbalanced load on the driving-shaft. The usual practice in making a test on a propeller at McCook Field is to obtain readings of the torque, thrust and speed, the deflections and change of pitch, at various speeds up to 50 per cent above the rated horsepower of the engine. This test is usually followed by a run at 50 per cent above the rated horsepower of the engine. It has been found that this test gives a satisfactory factor of safety for wooden propellers. For propellers of other materials, special tests are carried out according to requirements of the material. The readings

of thrust are obtained directly from the Toledo scale, and the readings of torque are taken both electrically and mechanically. The deflections are read by a telescope with cross-hairs which is adjusted until it lies in the plane of revolution of the leading and trailing edges respectively. A typical set of readings from one of these propeller tests is shown in Fig. 26.

A water-spray test also is arranged, and tests of the resistance to abrasion are run from time to time. One of the most complete tests carried through consisted of a 200-hr. run on a Micarta propeller designed for the Liberty Engine.

Tests of propeller material are of considerable importance, the quality of wood being usually determined by the specific gravity rather than by a strength test, owing to the great variation in results of strength tests, according to the method by which they are made, and depending upon the manner in which they are carried out. The specific-gravity test is very positive and appears to give a very clear indication of the quality of material. The most elaborate series of tests of wood with which the writer is familiar is that made by Mr. Newlin, of the Forest Products Laboratory. I have compiled some of the properties of a number of propeller woods, together with those of annealed steel and Micarta; these are given in Table 1.

HEAVY TRAFFIC PAVEMENTS

THE load-carrying capacity of any type or design of pavement must of necessity be influenced by the support afforded the pavement from below. Such support is furnished by that portion of the earth directly below the pavement, known as the subgrade. The supporting value of natural subgrades varies enormously, as illustrated by the two extremes of muck or quicksand and solid rock. Most subgrades consist of soil lying between the extremes mentioned but still varying greatly in their supporting value depending not only upon the type but upon the moisture content and the degree of compaction. With very few exceptions any well-compacted soil will of itself support the heaviest conceivable traffic if its moisture content is properly controlled and if it is protected by a structure which prevents the displacement of particles at its surface. The protective structure termed the pavement will then need to be only of sufficient thickness to afford such protection and at the same time itself withstand the various destructive agencies of traffic. For a given traffic this thickness will depend largely upon the type of pavement.

The bearing capacity of most soils, particularly the clayey types, decreases as their moisture content increases above a certain point. Although there is much yet to be learned regarding the comparative bearing value of soils this fact is generally recognized and various drainage methods are employed to control the moisture content of the subgrade. Proper drainage is the first essential for maintaining a dry subgrade and measures taken to prevent the access of water to the subgrade directly below the pavement are often more important than measures designed to remove the accumulations of water in the subgrade. Some soils are so persistently retentive of moisture once absorbed that it is impossible to remove it with sufficient rapidity by any ordinary system of drains. Certain clayey soils belong to this class and when all practical preventive measures in the way of drainage are likely to prove inadequate it may well be advisable to modify the character of the subgrade material. Thus at relatively low cost a clay subgrade can often be greatly improved by mixing it with sand in exactly the same manner as in the construction of a sandy-clay road. Such a mixture will not only retain less moisture than the clay but will possess a much higher supporting value than moist clay.

Any rational design of highway should take into account the fact that the subgrade must ultimately take the weight and shock of traffic as transmitted through the pavement and practically any reasonably dry subgrade will do this if it is compacted and its surface is protected from displacement. Careful attention to subgrade preparation and drainage is, therefore, the first essential to be considered.

The asphaltic concrete pavement is highly resistant to impact which is recognized as the most destructive traffic factor and under impact develops as a single unit relatively high slab and beam strength.

It is manifestly uneconomical, if not impracticable, to adopt a design of highway which will permanently bridge appreciable areas of weak subgrade. While the asphalt type develops bridging action to an appreciable extent it will of itself constantly seek to maintain contact with the subgrade at all points and thus reinforce itself with the maximum supporting value of the subgrade. The rigid type of pavement or base cannot do this because of its inherent characteristics. It is, therefore, almost sure to crack eventually where appreciable areas of subgrade fail to support it uniformly.

Both the service history of asphalt-base pavements and test data indicate that under given conditions it is not necessary to adopt as massive a design for the flexible type of base as for the rigid type. It is difficult for engineers who have had no opportunity to observe the asphalt-base pavement under heavy traffic to think of it in terms of less thickness than the rigid base but in the light of present experience such consideration appears to be entirely warranted.—From a paper presented before Engineers Club of Philadelphia, by Prevost Hubbard, chemical engineer, Asphalt Association.

COMPARISON OF ORDINARY WOOD WITH PLYWOOD

THE properties of wood in various directions relative to the grain differ widely and this variation must be recognized in all wood construction according to Technical Note No. 131 of the Forest Products Laboratory, Madison, Wis., and the difference in properties along and across the grain must be utilized to the best advantage by employing the proper size and form of parts. The tensile strength of wood parallel to the grain may be 20 times as great according to tests made at the laboratory as perpendicular to it and its modulus of elasticity is from 15 to 20 times as high. The shearing strength perpendicular to the grain is, however, much greater than parallel. The low parallel-to-the-grain shearing strength makes the utilization of the tensile strength of wood along the grain difficult, since failure will usually occur through shear at the fastening before the maximum tensile strength of the member is reached. The large shrinkage of wood across the grain with a changing moisture content may introduce distortions in a board that decreases its uses where a broad, flat surface is desired. The shrinkage from the green to the oven-dry condition across the grain for a flat-sawed board is about 8 per cent and for a quarter-sawed board about 4½ per cent, while the shrinkage parallel to the grain is practically negligible for most species.

It is not always possible to proportion a solid plank so as to develop the necessary strength in every direction and at the same time utilize the full strength of the wood in all directions of the grain. In such cases plywood meets this deficiency by cross banding which results in a redistribution of the material. In building up plywood an effort is made to obtian an equality of the properties in two directions.

Lubricating Oil Tests[1]

By Dr. W. H. Herschel[2]

THE object of tests of lubricating oil should be to determine suitability and durability, that is whether an oil is suitable for the purpose when new and whether it will be durable in service. It is important that these objects should be kept clearly in mind, since uniformity of test methods, which we all desire, can be secured only by uniformity of purpose in making tests

Gravity is sometimes used as a help in identifying a crude, but with the increased use of blends and of the Mid-Continent crude of mixed base the identification of crudes is becoming more and more difficult. It is also unnecessary and misleading, because there has never been adequate proof that just as good oils cannot be made from one crude as from another. Gravity is thus mainly of value as a correction in viscosity determinations, and it has been omitted from the Government specifications.

Viscosity is of prime importance in determining the suitability of an oil, but throws no light upon its durability. It tells nothing about deterioration in service but does enable an oil to be selected which will be suitable when new for the speed, pressure and temperature in the bearing where the oil is to be used. Apart from viscosity there is a property known as body or greasiness which determines suitability. There is no standard test for body, but it is known that with a sufficiently low speed and sufficiently intense pressure an oil of superior body will show lower friction. This has been proved in England by recent tests at very low speed,[3] and at the Bureau of Standards we have proved the same thing with high pressures by cutting off discs from a rod of cold-rolled steel. It should be noted that body determines suitability and not durability. In fact, the problem is to get as good a body as possible without too great a sacrifice of durability.

Coming now to tests for durability, we must consider how oils actually fail in service. Metallic contact or seizure is not necessarily an indication of deterioration of the oil, as it may be caused by the use of an oil of too low viscosity. The apparent failure of the lubricant, then would be due to underestimating the maximum temperature which would be reached in service, or to using an oil of a viscosity too near that of minimum friction. It is never safe to use an oil with a viscosity of minimum friction at the temperature of the bearing, but a more viscous oil must be used, the excess viscosity being necessary as a factor of safety against seizure.[4] If the factor of safety is made too low to decrease the friction, seizure may result, for which the lubricant is in no way to blame.

There are several emulsion tests in which the oil is subjected to a reproducible method of agitation with water, and the resistance to emulsification is measured by the rapidity of separation of the oil from the water after such treatment.[5] If an oil will meet this test satisfactorily, experience has shown that there will be no trouble from its emulsifying in use. Emulsion tests are also used to determine the purity of oils which are used in automobiles or in other machines where they do not come into contact with water. It has been found that if acid sludge is used as an impurity to contaminate a water-white lubricating oil, 0.1-per cent impurity is the maximum amount which could be used if the contaminated oil is to pass the requirements of a steam turbine oil. The selection of automobile oils is however a difficult problem which is by no means completely solved.

A test in common use is the carbon residue test which is based on the assumption that cracking of the lubricant takes place in an automobile cylinder. An examination of the cylinder deposit shows that this is only partly a cracked product, and that a large part is of an asphaltic nature and is therefore due to oxidation. There is, moreover, a possibility that some of the cracked product, real carbon, not the so-called carbon deposit, may be due to cracking of the fuel.[6] These considerations lead to the conclusion that the carbon residue test is inadequate alone and should be supplemented by an oxidation test. We are working at the Bureau of Standards on standardizing the oxidation test, the main difficulty being to design a reproducible oxidation oven.[7]

The owner of an automobile wants a test that will assure him the greatest mileage per gallon of oil. In other words, what is needed is a laboratory test that will indicate the consumption per horsepower-hour. The oil may evaporate in the course of circulation. To guard against excessive loss from evaporation we have, besides tests known as evaporation tests, the flash-point, which determines the volatility of the lightest fraction in the oil. The value of this last test is, however, greatly reduced by the fact that it gives no indication at all in regard to the amount of the light fraction present. The amount of the light fraction can be determined only by an evaporation test or a fractional distillation. While distillation of gasoline is common enough, the application of this test to lubricating oils has been delayed by the difficulty of making such a distillation without cracking. This difficulty has been overcome by the use of a high vacuum, the pressure being only 1.5 mm.

Crankcase oil may oxidize to such an extent that it will become more viscous after use, in spite of dilution from the fuel or from cracked products of the lubricant. If sediment is deposited it may clog the oil-passages and cut off the supply of lubricant so as to cause seizure. It is hoped by fractional distillation of new and used oils to determine what are the essential tests for automobile oils and how to interpret them. It is known that as a general rule the carbon residue test gives highest values for the most viscous oils, while, on the other hand, the oxidation test gives values for the least viscous. It is believed that by a comparison of fractional distillation tests of new and used oils it may be discovered whether the change or deterioration in an oil is mostly due to the light or to the heavy ends. If it is at the light end it would seem to indicate that the deterioration is by oxidation and that the oxidation test is the more important. If, on the other hand, the greater change in the fractional distillation curve should prove to be at the heavy end it would indicate that the carbon residue test is the more important.

In conclusion, I wish to emphasize the point that tests should not be made for identification of crude, as that proves nothing, but to determine the suitability when new or the durability in use. To believe that an oil will be good if made from a good crude is like believing that food will necessarily be good if made from good material. We all know better than to believe that.

[1] From a paper read at the annual meeting of the American Petroleum Institute, Washington, Nov. 18, 1920.

[2] Physicist, Bureau of Standards, Washington.

[3] See *Journal of the Society of Chemical Industry*, Vol. 39, p. 51 T for report of Lubricants and Lubrication Inquiry Committee, Department of Scientific and Industrial Research.

[4] See *Transactions of the American Society of Mechanical Engineers*, Vol. 37, p. 168, and *Zeitschrift für Mathematik und Physik*, Vol. 50, p. 97, for calculating the viscosity of minimum friction.

[5] See *Proceedings of the American Society for Testing Materials*, Vol. 20, part 1, p. 424.

[6] See *Chemical Age*, Vol. 4, p. 96.

[7] See Bureau of Standards Circular No 99, entitled The Examination of Petroleum, p. 103.

Resume of Bureau of Standards Fuel Study

By H. C. Dickinson[1]

Annual Meeting Paper *Illustrated with* Charts

REGARDING the problem of the relation between distillation range and fuel economy, there has been considerable thought devoted recently to the relation of fuel end-point to economy. Mr. Howard's very interesting paper on the subject of Volatility of Internal-Combustion Engine Gasoline[2] shows conclusively, I believe, that provided we secure an intimate mixture of fuel-vapor and air, such a mixture will not condense at the temperatures of the intake with which we are working. However, over against this we have the evident fact that at present we are having crankcase dilution, excessive carbon deposit, low mileage and trouble with the ignition. All of these are manifestations of excess fuel consumption. Therefore, it seems that there must be some gap in the explanation somewhere; in other words, what we should get does not tally with what we do get. It was with the view of throwing a little light on this discrepancy that the Bureau of Standards undertook a brief series of experiments to rough out, so to speak, a line of investigation. Before taking up this question, however, I wish to present a few observations on another subject.

A question often raised and which apparently has not been definitely answered regards the effect of compression on the dryness, or dew point, of the mixture of fuel and air. To develop definite figures on this subject, we have looked up such information as is available in published form and submit this in the form of a set of curves.

Fig. 1 shows that gasoline vapor compresses "dry." As Mr. Howard pointed out, each of the components in commercial gasoline has a definite vapor pressure at a definite temperature and, above some particular temperature, each one of the components will exist in the form of a vapor when mixed with air in any given proportion. Taking the rough assumption that the proportion of vapor to air is about 2 per cent by volume, we have at the left of the diagram a series of curves which represent, for several of the substances for which figures are available, the relation between the vapor pressure of the substance and the temperature, and at the right, adiabatic compression curves are plotted in millimeters of mercury and degrees centigrade, showing the pressures and temperatures for these same substances when mixed with air in the foregoing proportion. The various curves are plotted for different initial temperatures. The diagram is drawn so that at any point where the left-hand curves representing the various substances are above the adiabatic compression curves, the mixture will be dry; if they are below, the fuel will condense. The point of particular interest is that the adiabatic compression of a mixture invariably makes it very markedly dryer, so that there is an opportunity for vaporizing fuel to a considerable extent in the cylinder, due to compression alone. Thus a fog mixture of decane and air in the proportion of 1 to 15 and at 32 deg. fahr. if compressed to slightly less than half its volume will become dry. If the compression were to take place at a constant temperature rather than adiabatically, the result would be entirely different, the fuel being condensed rather than evaporated.

Fuel Characteristics and Economy

To throw some light on the relation between fuel characteristics and economy experimentally, we undertook a brief series of experiments with the equipment which was used for the report presented by Mr. James[3] last summer. I present the results with the belief that they do not represent truly what is average practice, but that they may point out certain limits which have not been well recognized before. The equipment referred to is a six-cylinder engine coupled with a dynamometer. It has a hot-spot manifold, equipment for measuring and controlling temperatures and pressures and for making such measurements as are desired, including measurements of acceleration.

I assume that typical driving conditions can be represented by a car speed of 20 to 25 m.p.h. and a horsepower which about corresponds to the average load of a car on the level at that speed. Typical conditions also involve very frequent acceleration; accelerations, for instance, of from 10 to 30 m.p.h. and, under these conditions, with an intake air temperature which is likely to be about 60 to 70 deg. fahr. and a normal amount of heat on the intake-manifold. In these experiments, the hot-spot on the manifold was cut out by blanking it off with a piece of asbestos, inserted between the intake and exhaust-manifolds. The immediate object of the experiments was to determine the difference, if any, in the amount of fuel burned to perform a definite amount of service under typical driving conditions as represented above, for three grades of gasoline; first, with aircraft gasoline, then with commercial gasoline and finally with aviation gasoline containing about 15 per cent of kerosene.

Two main types of experiments were undertaken. These were (*a*) steady runs to determine the rate of fuel consumption under load conditions, at about one-fifth the maximum mean effective pressure and a speed of 1200 r.p.m. and (*b*) a series of repeated accelerations from 10 to about 30 m.p.h. In each case the fuel consumption was recorded. The constant-speed runs were all made at the same speed and load and for the same length of time with special care exercised as to the conditions of air, water and oil temperature, so that the total number of horsepower hours was as nearly as possible the same in all cases.

[1] M. S. A. E.—Physicist in charge of power plants research, Bureau of Standards, Washington.

[2] See The Journal, February, 1921, p. 145.

[3] See The Journal, August, 1920, p. 133.

The acceleration runs each consisted of a series of accelerations following a period during which the engine idled with a closed throttle. The idling speed and adjustment and the stop to which the throttle was opened on acceleration were carefully regulated to assure the same engine speed on idling and the same throttle opening on acceleration for all runs. The idling and acceleration periods followed the same scheduled sequence and were of the same duration in all cases.

The load on the dynamometer depended upon the speed as determined by the characteristics of the dynamometer, the torque being nearly proportional to the speed. The control rheostats were adjusted the same in all cases; hence, the total horsepower-hours developed in all the acceleration runs were substantially the same. A watt-hour meter was not available but would have been desirable as a check on the equality of power output.

The schedule for each acceleration run was as follows:

(1) Adjust throttle to idle at 500 r.p.m. and adjust acceleration stop to give a speed of 1500 r.p.m.
(2) Idle for 30 sec.
(3) Open throttle to stop and observe time required to reach 1200 r.p.m.
(4) Maintain this speed for remainder of first 60 sec.
(5) Close throttle to idling position at 60 sec.
(6) Open to acceleration position at 90 sec.

The series was repeated five times.

The dynamometer equipment includes two fuel tanks arranged so that they can be supplied with different fuels and the supply to the engine quickly changed from one to the other.

In these experiments two of the three fuels, first aviation gasoline and commercial were supplied and a single run, as described above, was made, first with aviation gasoline with a selected carbureter adjustment and repeated with commercial gasoline and the same adjustment; then the carbureter adjustment was changed to a leaner one and a run taken with commercial gasoline, then with aviation gasoline and the same adjustment. In this way five values of mixture ratio were run, the fuels being alternated between each pair of runs. A series of comparisons were similarly made between the aviation gasoline and this fuel plus 15 per cent of kerosene.

The results of these runs have been rather carefully tabulated, but an examination of the tabulation yields one result, namely, that for the conditions here adopted there is no significant difference in the total amount of either of the three fuels consumed, reckoned in pounds, to deliver the same amount of horsepower hours under the same conditions. I wish to repeat that I do not believe that these observations show that the fuel consumption in service is independent of the fuel composition. They do show, however, that the induction system of the particular engine used for these tests was unusually good, as the intake temperature was only about 125 deg. fahr.

What Is Detonation?

There has been much discussion as to precisely what the phenomenon of detonation really amounts to physically; as to the precise physical performance inside an engine cylinder when it develops the sound which we call detonation. Some of our colleagues at the Bureau of Standards have been inclined to question very carefully every proposal which has been set forth. Mr. Sparrow suggested sometime ago that he wanted to prove whether what we recognize as detonation or fuel knock could not

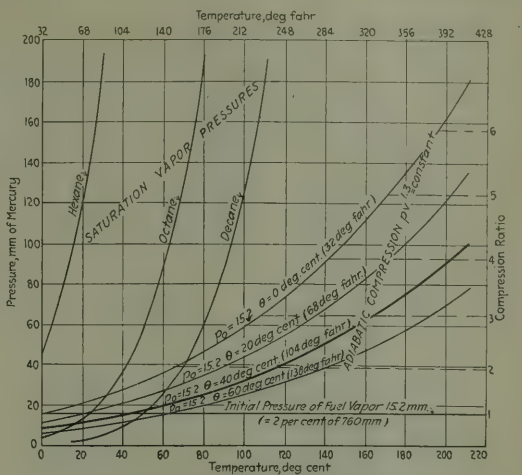

Temperature, deg fahr
32 68 104 140 176 212 248 284 320 356 392 428
200 180 160 140 120 100 80 60 40 20 0
Pressure, mm of Mercury
Hexane
SATURATION VAPOR PRESSURES
Octane
Decane
ADIABATIC COMPRESSION PV^1.3=constant
Compression Ratio
6 5 4 3 2 1
Pa=15.2 θ=0 deg cent (32 deg fahr)
Pa=15.2 θ=20 deg cent (68 deg fahr)
Pa=15.2 θ=40 deg cent (104 deg fahr)
Pa=15.2 θ=60 deg cent (138 deg fahr)
Initial Pressure of Fuel Vapor 15.2 mm.
(=2 per cent of 760 mm)
0 20 40 60 80 100 120 140 160 180 200 220
Temperature, deg cent

Fig. 1—Series of Curves Showing That Gasoline Vapor Compresses Dry

after all be an aggravated piston slap. We have a one-cylinder Liberty engine which has served many experimental purposes. This engine was fitted with a piston about 1/10 in. too small in diameter which produced a most aggravating slap, as was intended. There being no doubt about the presence of the piston slap, we stood some chance of finding whether the detonation and the piston slap were the same or not. After some adjustment, it was possible to get detonations in conjunction with the piston slaps. The two things are distinguished very easily and no other proof seems necessary that they are entirely independent.

Following these observations we became interested in recording some of the facts, or apparent facts, which can be established with regard to the phenomena of detonation, particularly those which can be verified by physical measurements. The one-cylinder Liberty engine is admirably adapted for such observations as the parts can readily be replaced and it can be modified to meet experimental conditions. The cylinder at present in use is fitted with openings for three spark-plugs, permitting at least one to be used for experimental purposes such as mounting an indicator or a window for looking into the cylinder without interfering with ignition. When observing the conditions which affect detonation, it is desirable to make these observations under conditions such that detonation is just on the verge of occurrence or non-occurrence. Under these conditions the phenomenon is most sensitive to changes in conditions. Accordingly, all observations discussed hereafter were made with the engine throttled to about 60 lb. mean effective pressure and a speed of approximately 1100 r.p.m. Under these conditions, the cylinder developed 10 to 11 hp. and detonation was easily brought in or prevented by slight changes in the conditions of operation. Commercial gasoline was used in most of these experiments.

One of the most significant features of the phenomenon to me is its discontinuity. By discontinuity I mean that the detonation knock is as definite a physical thing as the explosion; it either occurs or it does not occur. When it occurs it occurs with considerable violence; and when it does not occur it is entirely absent. In this sense, there

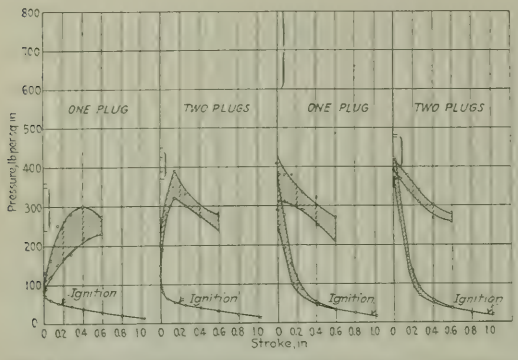


FIG. 2—CURVES SHOWING THE MAXIMUM EXPLOSION PRESSURES DEVELOPED WITH ONE AND TWO SPARK-PLUGS

is something in the phenomenon which is in the nature of a physical discontinuity; it fires or it does not. To illustrate, if we gradually increase the intensity of the spark in a cylinder which is being fed with fuel mixture, the charge will not fire as long as the spark is too weak, but at some point it will begin to fire irregularly; some strokes will be accompanied by an explosion, while others will not. Similarly as regards detonation, some strokes are accompanied by it and some are not, and it is usually very easy to distinguish between them, although the intensity can be varied widely.

For the most part, observations were made with the conditions substantially constant, except for changes in the timing and changes from one to two spark-plugs. The water temperature was maintained at about 70 to 75 deg. fahr. constantly; the mixture ratio was kept constant under all conditions, and carefully checked to see that it did remain constant. It soon developed that it was very easy to get a perfectly definite detonation with one spark-plug and no detonation with two spark-plugs, all other conditions remaining fixed. That has been noticed many times and is explained naturally by the theory of the detonation waves. But, carrying it further, Mr. Sparrow showed that it is almost as easy to get detonation with two spark-plugs, while not with one spark-plug. That is not so simply explained on the basis of the accepted detonation-wave theory, although the fact may prove to be consistent with this theory.

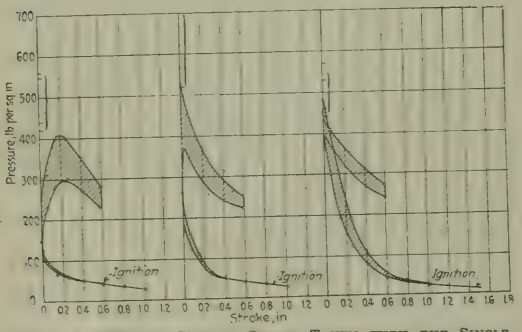


FIG. 3—A SERIES OF SIMILAR CURVES TAKEN WITH THE SINGLE SPARK-PLUG
The Curve at the Left Represents the Maximum Power, That in the Center the Maximum Detonation and the One at the Right the Effect of a Moderate Preignition

The most obvious conclusion from these experiments is that, whatever the nature of detonation, it is largely dependent upon the timing of the explosion with respect to the position of the piston. This does not mean necessarily the timing of the ignition spark, but rather the time at which the maximum rate of burning takes place. For instance, when firing from two spark-plugs at opposite sides of the cylinder, the maximum rate of burning will occur a much shorter time after ignition than when firing from a single spark-plug. If, therefore, the ignition time is the same in the two cases, firing from two plugs instead of one will in effect advance the ignition and vice versa.

Thus, if the ignition timing in the present experiments was such as to produce detonation with two spark-plugs, cutting out one plug had the effect of retarding the time of burning sufficiently to prevent detonation. On the other hand, if the timing was such as to produce detonation with one spark-plug, cutting in a second plug had the effect of advancing the time of burning and preventing detonation by this means. These effects are shown in the several illustrations described below.

Another phenomenon noticed is the fact that the temperature of the jacket water, or the heat lost to the jacket, was materially affected by the fact of detonation or not. The intake water for this engine was kept at a nearly constant temperature and the rate of flow was substantially constant; consequently, it was easy to determine roughly the amount of heat supplied to the water-jacket by measuring the temperature of the outlet water and, under all conditions where detonation was produced, a very marked rise of temperature in the jacket developed. I believe that the actual amount of heat supplied to the water-jacket was in some cases almost 30 per cent greater when detonation was produced than when it was not produced. Accompanying that increase in heat to the jacket there was usually a small dropping off in the mean effective pressure, but the dropping off in the mean effective pressure by no means accounted for the actual extra heat lost. The source of the apparent extra energy, as well as the general effect of detonation on heat distribution, might be worth careful consideration.

FURTHER DETONATION EXPERIMENTS

Following the foregoing experiments, an indicator was mounted on the cylinder and a series of indicator cards were taken under varied conditions to throw more light on the exact conditions accompanying detonation. It should be borne in mind that all these experiments were carried out at pressures which were just on the verge of detonation. Most of the observations which have been made along this line have been at full load and under conditions where the maximum pressures often were considerably higher than is necessary to produce this phenomenon. With compressions barely high enough to produce detonation, it might be expected that the phenomenon would be much more sensitive to pressure and ignition timing than if we were working under less carefully controlled conditions. Even at these compressions, maximum pressures in the cylinder of far above 1000 lb. per sq. in. were developed repeatedly. Incidentally, the pressure on the wrist-pin was somewhat over 8000 lb. per sq. in.; I believe it was 10,000 lb. per sq. in. in some cases.

The curves in Fig. 2 were plotted in terms of the distances of the piston from its center position, in tenths of an inch. The point of ignition is shown on the various curves. The shaded area represents the area between

which the maximum and the minimum pressure occurred in any cycle. The indicator we are using is one which enables us to plot the maximum, minimum and intermediate pressures in the cylinders, for each position of the crankshaft. The brackets to the left indicate the range of maximum pressures which were measured, independent of the position in the stroke. In the two curves at the left, the ignition time was the same but the time of burning was advanced in the second case due to ignition by two spark-plugs instead of one. The next curve to the right was produced with one spark-plug. The much higher peak pressure should be noticed in this case. The detonation knock was present in this instance and the bracket at the top shows the presence of very high maximum pressure, accompanied by very marked detonation knock, in fact, an intolerable noise. The curve farthest to the right represents the absence of

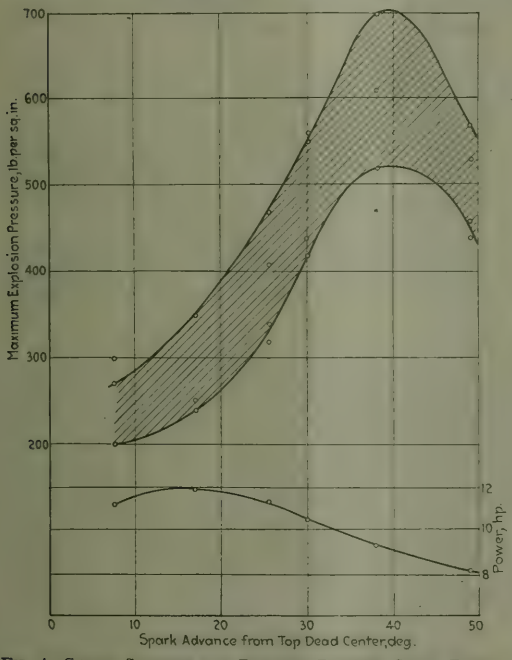


FIG. 4—CURVES SHOWING THE RELATION BETWEEN SPARK TIMING AND THE MAXIMUM PRESSURES REACHED IN THE CYLINDER

detonation with two spark-plugs, the ignition timing being the same as for the previous curve. Ignition is obviously too early in this case as shown by the shape of the curve at the maximum pressure, but little or no knock was observed.

Fig. 3 shows similar curves that were all taken with one spark-plug. The curve toward the left represents normal burning. The point of ignition is 0.6 in. below top dead-center. The first curve represents the maximum power and the second represents the maximum detonation with the single spark-plug. In this case the maximum pressure range is 500 to 700 lb. per sq. in., the normal compression range being 375 and 525 lb. per sq. in. This curve represents a marked loss of horsepower, as compared with the former. The third curve represents the effect of moderate preignition; then the

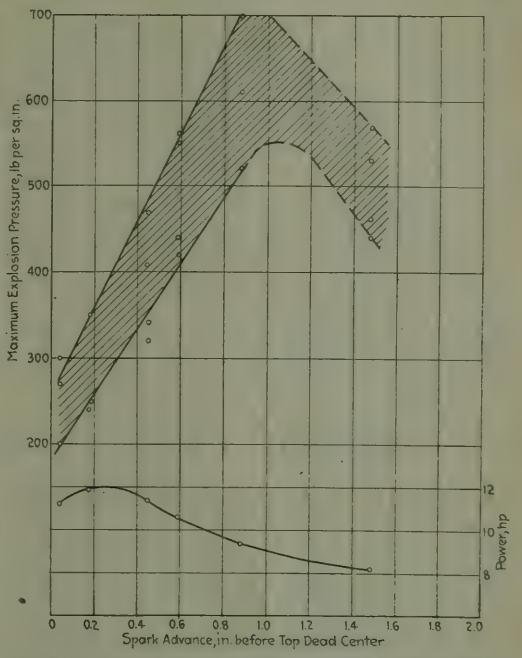


FIG. 5—A SIMILAR SET OF CURVES TO THOSE GIVEN IN FIG. 4 EXCEPT THAT THE TIMING IS PLOTTED IN INCHES FROM THE TOP DEAD CENTER INSTEAD OF DEGREES

pressure drops during the dead-center period, due to cooling of the cylinder walls or to leakage. This drop of pressure during the compression period may be due partly to actual leakage and partly to cooling of the charge, which is at a very high temperature. It should be noted that the maximum pressures as indicated by the brackets are only about the same as in normal operation, as shown by the first of the three curves, and the knock is no more pronounced.

Fig. 4 is plotted to show the relation between spark timing and the maximum pressures reached in the cylinder, also the power output. The upper curve represents the range of maximum pressures which occur in the

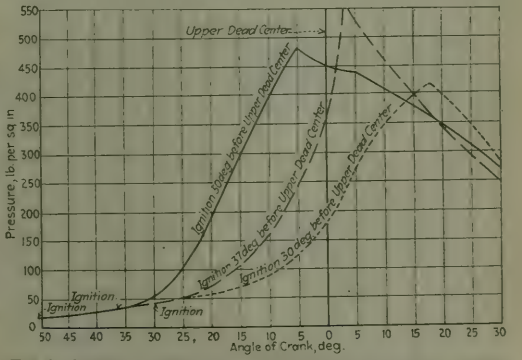


FIG. 6—CURVES SHOWING HOW A VARIATION IN THE POINT OF IGNITION CHANGES THE MAXIMUM EXPLOSION PRESSURE

cylinder versus the spark timing. For instance, at a 20-deg. advance, the pressures ranged from 265 to 390 lb. per sq. in. and with a 40-deg. advance, the pressures were highest. In comparing these with the power output, it is seen that a 15-deg. advance or slightly more, the power was maximum, and at a 40-deg. advance, there was a drop of from approximately 12 to 8½ hp., accompanied by an increase of more than 100 per cent in the maximum pressure.

Fig. 5 is the same as Fig. 4, except that instead of being plotted in degrees, the timing is plotted in inches from top dead center. Both the lower and upper limits are almost straight lines, on both sides; that is, they show almost a linear relation between the position of the piston and the maximum pressure. The maximum power is secured at an ignition point of about 0.3 in. below dead center. Detonation takes place most severely at the point of maximum pressure. This suggests, in this case at least, why it is possible to get detonation with two spark-plugs and not with one spark-plug, and vice versa, depending upon the timer setting.

Fig. 6 gives the data plotted in Fig. 3, in pressure-time coordinates. Hence the curve to the left represents normal conditions, the middle curve the maximum detonation as produced by change of spark timing alone, and the right-hand curve shows the characteristics of too early ignition.

The foregoing are only a few of the facts and fancies regarding the phenomenon of detonation. There is much more that we think we know and still more that we think we can see and hear. We may never acquire a complete and definite knowledge of the real nature of the phenomenon, and it might be of little practical value if we do. So long as such an obvious and important problem remains unsolved, we can hardly cease to look for its solution and hope that when found the solution will be of importance commensurate with the complexity of the problem.

MOTOR-VEHICLE SAFETY INCREASING

AUTOMOBILE use is growing constantly safer. Official figures show a steady decline in the ratio of fatalities to the number of cars in operation. Automobile deaths per car were 0.0025 in 1914, and have been reduced to 0.0013 in 1919. Statistics for the year 1920 in Detroit and New York City show that the former city registered one less fatality due to automobiles than in 1919, and New York's toll was 21 less than the 1919 mark. The reduction of 50 per cent in 5 years in the ratio of fatalities to the number of cars shows that the public is quickly adapting itself to the problems of congestion, and continued progress in motor-vehicle safety is confidently looked for.

DEATHS CAUSED BY AUTOMOBILES IN THE UNITED STATES FROM 1914 TO 1919

Year	Number of Automobile Deaths per Car	Total Number of Automobile Deaths	Registration of Cars	Cars per 1000 Population	Automobile Deaths per 1000 Population
1914	0 0025	4,231	1,711,339	17	0 0428
1915	0 0024	5,928	2,445,664	24	0 0591
1916	0 0021	7,397	3,512,996	34	0 0725
1917	0 0019	9,184	4,983,340	48	0 0887
1918	0 0016	9,672	6,146,617	59	0 0919
1919	0.0013	9,827	7,558,848	71	0 0936

The figures of fatalities show that some gain is being made in the safety of motor transportation when the increasing number of units is taken into consideration. Moreover, it is believed by the National Automobile Chamber of Commerce that a constant improvement in safety can be achieved through the adoption of uniform traffic laws and the education of truck owners on the dangers of overloading. Figures showing the relation of car fatalities to the various factors having a bearing on accidents are given in the accompanying table and indicate a decline of 50 per cent in the ratio of fatalities per car.

The total number of deaths caused by automobiles in the entire United States was estimated by the National Workmen's Compensation Service Bureau which applied the Census Bureau figures for the registration area to the entire country.

Proposed Remedies

Many accidents are caused by the varying rules of the road in different States which leads to the confusion of drivers in interstate traffic. The Motor Vehicle Conference Committee, composed of car builders, dealers, owners and allied bodies urged a proposed uniform vehicle law before legislatures this past winter. This measure contains provisions which, if adopted by the states, will set a standard code for driving and thereby enhance the safety of the interstate drivers. This law also would require every vehicle to carry certain equipment all of which is conducive to the safety of the travelling public. This equipment consists of brakes in good working order, horns or other signalling devices, regulations concerning lamps and other safety specifications.

Attempts will be made to educate the truck owner on the dangers of overloading. Legal restrictions on this are helpful, but evasion is so easy that the final appeal must be to the user. Overloading injures the truck and shortens its life. Overloading is highly dangerous to the driver and to pedestrians as the brakes of a vehicle cannot function at 100 per cent efficiency when the truck is carrying more than its rated burden.

VARYING THE NUMBER OF PLIES IN PLYWOOD

FREQUENTLY the question arises in making up plywood for a particular use as to whether three or more plies should be used to obtain the required thickness. According to Technical Note No. 132, issued by the Forest Products Laboratory, Madison, Wis., increasing the number of plies decreases the tensile and bending strength parallel to the grain of the faces and increases the strength at right angles to the grain of the faces. If the same bending or tensile strength is desired both parallel and perpendicular to the grain of the faces, increasing the number of plies will tend to give this result. If on the other hand greater strength is required in one direction than in the other a three-ply panel is preferred since plywood with a large number of plies while stronger at right angles to the grain of the faces cannot be as strong parallel to the grain of the faces as three-ply wood. Where great resistance to splitting is required as in plywood that is fastened along the edges with screws and bolts and subjected to forces through the fastenings, a large number of plies affords a better fastening.

A glued joint is more likely to fail when thick laminations are glued with the grain crossed than with thin layers and this weakness exists in plywood with thick plies.

DATA ON ILLINOIS TRACTORS

THE data used in this discussion were taken from a tractor survey made by the Division of Farm Mechanics, University of Illinois, and comprise records kept by farmers on 68 tractors. The tractors were divided into three groups, namely, two-plow, three-plow and four-plow machines. Table 1 shows this grouping with the rating and number of tractors considered. It must be remembered that the figures given for each group are the average for all tractors in that group.

TABLE 1—THE TRACTORS GROUPED BY RATINGS

Number of Plows	Rated Horsepower	Number in Group	Total Number
2	6–12	4	
	8–16	8	
	9–18	5	17
3	10–20	23	
	12–25	21	44
4	15–30	3	
	18–36	3	
	20–40	1	7

The size of farm upon which the tractor can be used profitably in the corn belt varies a great deal with the system of farming. A 160-acre farm is considered about the minimum in the corn belt for the profitable use of a tractor, but in one instance a three-plow tractor was operated on a 100-acre farm at a lower total annual expense than the horses which it replaced.

TABLE 2—SIZE OF FARMS AND ACREAGE IN CROPS

Size of Tractor	Two-plow	Three-plow	Four-plow
Size of Farm, acres	258	298	309
Planted Area, acres	186	203	210
Planted Area, per cent	72.0	68.3	68.0
Corn Area, acres	89	85	82
Corn Area, per cent	48.0	46.7	39.0
Small Grain Area, acres	81	97	108
Small Grain Area, per cent	43.5	47.8	51.5

Table 2 shows the size of the farms and the acres in corn and small grain. A study of this table will show a decreasing percentage in acres devoted to crops as the size of the farm increases; also a decrease in the acreage of corn and an increase in the acreage of small grains as the size of the tractor increases. The average size of the farms on which two-plow tractors were used was 258 acres, and 298 acres with the three-plow tractors, representing but a small difference between the average size of the farms on which the different sized tractors were used.

It is generally conceded in these reports that soil packing does not result harmfully. Only four of the 68 operators reported harmful results from packing; nine reported harmful results when the soil was wet.

Number of Days Tractor Is Used

There is much agitation at the present time to put the tractor to a greater variety of uses on the farm. Table 3 shows the number of different days, hours, and hours per day that the various tractors were used. At a glance we would say that the tractor is not used enough days to make it pay. Thirty to fifty days of use will be about the average where the tractor is used on the farm only. It must be kept in mind that the tractor is used mainly during the period of peak loads which occur in April, May, June, October and November. At other times the horses that must be kept on the farm can take care of most of the work. The comparatively small number of hours the tractors were used per day, on the average, is not an indication of inefficiency, for in almost every case these days were full days.

TABLE 3—DAYS TRACTOR WAS USED AND HOURS OF TROUBLE IN THE FIELD

Size of Tractor	Two-plow	Three-plow	Four-plow
Days Used	34.4	35.0	55.0
Hours Used	233	255	342
Use per Day, hr.	6.77	7.28	6.21
Trouble in Field, hr.	9.04	7.40	10.60
Time Lost on Account of Trouble, per cent	3.87	2.90	3.09

It is interesting to note in Table 3 that there is a slight decrease in the percentage of actual tractor trouble in the field, as the size of the tractors increases. The individual records show that, contrary to general opinion, the kerosene-burning tractors were as free from trouble as those burning gasoline.

The different operations performed by these tractors were as follows:

Traction Work

(1) Plowing
(2) Discing
(3) Harrowing
(4) Drilling
(5) Harvesting
(6) Cultivating Corn
(7) Pulling Corn Pickers
(8) Pulling Hay Loaders
(9) Hauling Manure
(10) Pulling Posts
(11) Moving Building
(12) Grading and Dragging Roads
(13) Grading Ditches

Belt Work

(1) Threshing
(2) Silo Filling
(3) Shelling Corn
(4) Shredding Corn
(5) Baling Hay and Straw
(6) Hulling Clover
(7) Grinding Corn
(8) Running Grain Elevator
(9) Sawing Wood

All of these operations can be handled profitably with the tractor, if the machine is of the proper size for the particular job.

An idea of the work done per hour by the tractors can be gained from a study of Table 4. The low figure in the case of discing with the four-plow tractor is due to an insufficient number of discs for a full load.

TABLE 4—WORK PER HOUR

Size of Tractor	Two-plow	Three-plow	Four-plow
Plowing, acres per hr.	0.733	0.813	1.191
Discing, acres per hr.	1.470	2.050	1.790
Harvesting, acres per hr.	1.890	2.170	2.470

Very favorable reports were given as to the reduction of the hired-help bill; 7 per cent of the operators reported no effect, but indicated more time available for odd jobs; 5 per cent reported a saving of from 10 to 50 per cent in hired help.

Replacement of Horses

In studying this problem there are two viewpoints to be considered, namely, the number of horses displaced by the tractor and the increase in crop acres per horse, both of which are shown in Table 5. The latter method is the most logical

TABLE 5—HORSES REPLACED AND INCREASE IN CROP-ACRES PER HORSE

Size of Tractor	Two-plow	Three-plow	Four-plow
Original Number of Horses	8.3	10.4	11.7
Horses Used after Tractor was Purchased	5.6	7.2	8.2
Horses Replaced by Tractor	2.7	3.2	3.5
Crop-Acres per Horse before Tractor Was Bought	22.4	19.5	17.9
Crop-Acres per Horse after Tractor Was Bought	33.2	28.2	25.6
Increase in Crop-Acres per Horse, per cent	48.3	44.5	43.0

TABLE 8—GASOLINE, KEROSENE AND OIL CONSUMPTION

Size of Tractor	Fuel Consumption gal. per hr.		Fuel Consumption per Acre Plowed, gal.				Fuel Consumption per Acre Disced, gal.				Fuel Consumption per Acre Harvested, gal.			
	Gasoline	Kerosene	Gasoline	Oil	Kerosene	Oil	Gasoline	Oil	Kerosene	Oil	Gasoline	Oil	Kerosene	Oil
Two-plow	1.490	1.870	1.860	0.144	3.090	0.251	1.170	0.096	1.560	0.080	0.790	0.057	0.850	0.073
Three-plow	1.870	2.260	2.450	0.152	2.760	0.190	0.900	0.050	1.270	0.081	0.700	0.053	1.000	0.072
Four-plow	2.640	2.360	2.700	0.208	1.450	0.077	1.500	0.125	0.140	0.065	0.890	0.050	0.700	0.024

basis for comparison. Some of the farmers did not dispose of any horses, but increased the crop acreage per horse. An average of all the farmers using tractors shows an increase from 20 crop-acres per horse where horses were used to 29 crop-acres per horse where tractors and horses were used, an increase of 49.5 per cent. Again we find that as the size of the tractor increases the crop-acres per horse decreases. Where two-plow tractors were used there were 33.2 crop-acres per horse, while with the four-plow tractors this was reduced to 25.6 crop-acres per horse, indicating a lessening of the utility of the horse. These farms were average corn-belt farms, growing corn and small grains. Corn takes almost twice as much horse labor per acre as small grains, and it is logical to conclude that the larger farms were not making as efficient use of their horse labor as were the smaller farms.

TABLE 6—COMPARATIVE COST OF TRACTORS AND HORSES

Size of Tractor	Total Annual Cost of Tractor	Horses Replaced	Cost of Keeping Horses
2	$382.62	2.7	$353.00
3	388.18	3.2	419.00
4	637.99	3.5	457.00
5	937.08	2.0	262.00

Table 6 brings out some very interesting results concerning the tractor and horse question. The following values were used for the tractor as a basis of comparison: Depreciation 20 per cent, interest on investment 6 per cent, gasoline 23 cents per gal., kerosene 13.5 cents per gal., and actual cost of repairs. No credit was allowed the tractor for the belt work done, the hired help which it displaced, and no depreciation was allowed on the horses.

The cost of horse labor which is based on cost accounts kept by the Farm Management Department of the University of Illinois during 1917 is given in Table 7.

TABLE 7—COST OF KEEPING A HORSE IN 1917

Feed	$103.18
Labor	11.80
Interest	7.79
Shelter	2.91
Harness	3.72
Miscellaneous	1.54
Total	$130.94

In view of the above considerations the three-plow tractors operated at a lower annual cost than the horses which they replaced. If we were to consider the belt work done and the hired help which the tractor displaced, the figures would be much more in favor of the tractor. The above statements are upheld by the fact that 57, or 88.7 per cent of the operators reported that their tractors had been profitable investments.

The kerosene, gasoline and oil consumption of the tractors is shown in Table 8. In practically all cases more kerosene than gasoline is used per unit of work; 20 per cent more kerosene than gasoline. There is a tendency toward less kerosene consumption per unit of work as the size of the tractor increases. The oil consumption for kerosene machines is greater than for gasoline tractors in all operations except discing. The oil consumption of the different machines varies greatly, since much is dependent upon the individual operators.

Repairs

The records show a slightly lower repair bill for kerosene burning tractors. The average age of the 68 tractors considered was 2.3 years, and the average repair bill 3.4 per cent of the original cost of the tractors. The tractors range in age from 1.25 to 4.60 years. A marked increase in the repair bill can be expected as the tractor becomes older. At the present time the average life of a tractor is considered to be about 5 years. Much can be done to reduce the repair bill and lengthen the life by careful care and operation.

TABLE 9—TOTAL ANNUAL COST OF TRACTOR OPERATION

Size of Tractor	Two-plow	Three-plow	Four-plow
Fuel	$112.86	$90.50	$173.70
Lubricants	31.93	20.85	56.72
Repairs	34.29	32.60	14.16
Miscellaneous Items	2.00	4.70	5.11
Depreciation	170.80	202.82	329.40
Interest	30.74	36.71	58.90
Total	$382.62	$388.18	$637.99

The total annual cost of operating the tractors is given in Table 9. It should be noted that fuel and depreciation are the big items of the operating cost. The low total fuel consumption for the three-plow tractors is due to the fact that several of the machines were used very little. The records tend to show that there is a general tendency for increased cost of operation in the gasoline burning machines, while in kerosene burning machines the tendency is to reduce the cost. On corn-belt farms of 160 acres or more the proper sized tractor will operate at a cost equal to or less than that of the horses it displaces.—R. I. Shawl in *Orange Judd Farmer.*

LARGEST INTERNAL-COMBUSTION ENGINE VESSEL

THE largest vessel fitted with internal-combustion engines now in service was recently completed at Krupps' yard at Kiel, Germany. This is the motor tank-vessel Zoppot. She has a dead-weight carrying capacity of 15,000 tons, and is 525 ft. in length, with a beam of 66½ ft. She is equipped with two Diesel engines, each of 2000 b.hp., constructed by Krupps. They are of the two-stroke single-acting type, with six cylinders 22⅝ in. in diameter and having a 39⅜ in. stroke, and are very similar in design to engines constructed by the same builder before the war. Although most European oil-engine builders adopt port scavenging now for two-cycle engines, in the Krupp engines the old arrangement of scavenging by valves in the cylinder cover is retained.—*Engineering Supplement, The Times* (London.)

National Advisory Committee's 5-Ft. Wind Tunnel

By F. H. Norton[1]

Illustrated with Photographs and Drawings

IN the spring of 1919 work was started on a 5-ft. wind tunnel for the National Advisory Committee for Aeronautics at Langley Field, Va., and in the spring of 1920 the tunnel was completed and ready for calibration and for conducting tests. This tunnel has now been in operation for about one year and during that time new apparatus and equipment have constantly been added to increase its efficiency and usefulness. While the tunnel is not as large as some that are now in use, it has, it is believed, the highest useful speed of any wind tunnel in the world, that is, it maintains a high velocity flow which is steady in speed and direction, and it possesses satisfactory means for measuring the forces on models at the highest velocities. At present, useful speeds up to 120 m.p.h. can be attained; but, as the propeller was originally designed for other conditions, it is estimated that with a new and higher-pitch propeller a maximum speed of 140 m.p.h. can be reached. Testing models at such high velocities is not a simple matter and a number of new methods and devices had to be developed to accomplish this successfully. For this reason a large portion of the time that the tunnel has been in active operation has been occupied in carefully studying the aerodynamic properties of the tunnel and in constructing apparatus for holding models at the high velocities which can be reached so that only in the last few months has the tunnel been devoted continuously to research work. From now on, the work of the tunnel will be devoted almost exclusively to tests on thick airfoils, including an investigation of their pressure distribution, and to study the stability of model airplanes.

Tunnel and Building

The wind-tunnel building, which is constructed substantially of brick and steel, is approximately 92 ft. long, 43 ft. wide, and 28 ft. high at the eaves. In Fig. 1 is shown a longitudinal section of the building and tunnel giving the principal dimensions of the structure. A heavy concrete foundation runs the whole length of the tunnel and a separate foundation is used for the power-plant, so that any vibrations which may be set up by the propeller or motor are not directly transmitted to the tunnel or balance. The interior of the building is smooth and free from obstructions so that the return flow of air from the tunnel will be disturbed as little as possible. Large doors at one end of the building allow the circulation of outdoor air for cooling the building in summer, which is necessary because of the rising temperature due to the power loss in the tunnel at the higher speeds, although, of course, these doors cannot be open while the actual tests are being carried on, owing to possible disturbances from the wind. Besides the main room for the tunnel there are several small rooms for offices in the building.

[1]Jun. S. A. E.—Chief physicist, National Advisory Committee for Aeronautics, Langley Field, Hampton, Va.

[2]See National Advisory Committee for Aeronautics Reports Nos. 73 and 98.

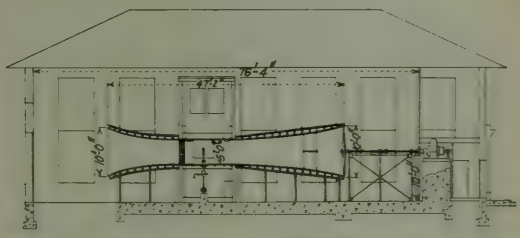


Fig. 1—Longitudinal Section of the Wind-Tunnel Building and the Tunnel

The tunnel itself is of the venturi type with a continuous throat of circular section, and there is an air-tight experimental chamber built about the working section in order that small holes may be opened into the tunnel while it is running, without disturbing the airflow; and this chamber has proved of great convenience in much of the work. The tunnel expands, as shown in Fig. 1, from the 5-ft. diameter working section to a diameter of 10 ft. at the mouth of the entrance and exit cones. This type of tunnel was selected after a considerable amount of investigation had been made upon a model tunnel 1 ft. in diameter, by measuring its efficiency and steadiness while varying many of its characteristics, especially the form of the cones, the type of the experimental chamber, the diffusers and honeycombs.[2] It will be noted that, contrary to usual practice, no diffuser is used in the return flow, and this is because the gain in steadiness from its use was found to be very slight on the model, while the cost of the full-sized diffuser would be considerable. Taking into consideration the aerodynamic efficiency of the tunnel, the cost of construction and the steadiness of the air flow, this type of tunnel was considered to be the best for the proposed investigations, although for some classes of work a larger diameter and slower speed tunnel would be more advantageous.

The cones of the wind tunnel as shown in Fig. 2 are supported from a concrete foundation by heavy steel-work and the surface of the cones is planked with cypress with the inside highly polished. This construction may at first seem unduly heavy but when it is realized how great are the vibrations set up by the higher wind speeds and the necessity for having the cones remain perfectly true, it is evident that such a construction is quite justified.

The experimental chamber, which is about 10 ft. long, 14 ft. wide, and 23 ft. high, is built around four concrete columns of very massive construction to withstand the heavy pressures, in some cases as much as 80 lb. per sq. ft., that arise during the high-speed runs. The lower story of the experimental chamber contains the National Physical Laboratory balance and the controlling devices for the air speed, while the upper story contains the propeller dynamometer and wire type of balance. The

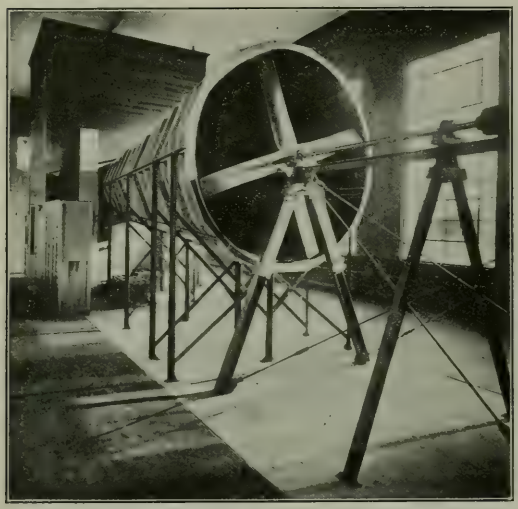


FIG. 2—GENERAL VIEW OF THE TUNNEL

chamber is entered either by a large door when the tunnel is not running, or when it is necessary to enter with a difference in pressure, an air lock is provided which consists of two small doors with air valves. Adjustments are made on the model through large doors which can be opened in the throat of the tunnel, these doors being curved to fit the section of the throat. In order that the model may be inspected during a test, there are three curved glass windows set flush with the inner surface of the tunnel, two in the floor of the tunnel and one in the top. Besides these inspection windows there are also four illuminating windows with electric bulbs, providing a powerful light for photographic purposes. A general view of the lower story of the experimental chamber is shown in Fig. 3, with one of the curved tunnel doors open, indicating the ease with which the model may be reached for adjustment.

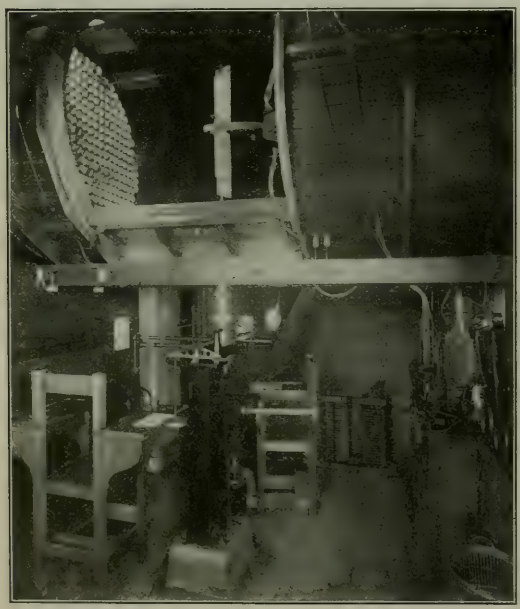


FIG. 3—INTERIOR OF THE EXPERIMENTAL CHAMBER SHOWING A MODEL SET UP FOR PRESSURE DISTRIBUTION TESTS ON THE TAIL PLANE

POWERPLANT

The driving motor consists of a 200-hp. direct-current, adjustable-speed motor, with a speed range of from 1 to 1000 r.p.m. At present power is supplied to this motor at 250 volts from a dynamo driven by a Liberty engine in an adjacent building, but as this powerplant is expensive and inconvenient it is hoped that a more suitable source of supply will soon be available. The propeller is direct connected to the motor by a 3-in. shaft supported on a steel framework and mounted in three ball bearings, while the propeller itself is 10 ft. in diameter and has four blades. As this propeller was designed to be driven by a Liberty engine at 1400 r.p.m. it does not at present absorb all the power which the electric motor can deliver and a new propeller with a larger number of blades and a higher pitch is soon to be used which will increase the air speed obtainable in the tunnel to a considerable extent. The main switchboard is at the entrance of the building, and to obviate the necessity of running heavy wires down to the experimental chamber, the control is by automatic push buttons, one for starting and one for stopping, while a field rheostat is used for speed control above the normal rate of 250 r.p.m. and a series rheostat or potentiometer for speeds below this. The rheostats are placed outside of the experimental chamber to eliminate the heat which would raise the temperature in the small chamber to an uncomfortable degree.

In Fig. 4 is shown a curve of power input to the driving motor plotted against the air speed in the throat of the tunnel. It should be noted that the efficiency of the motor with the very small field excitation which occurs at the higher speeds is exceedingly low and the actual power supplied to the tunnel is much less than that supplied to the motor. An approximate energy factor for the tunnel and propeller of 1.90 is obtained, showing an efficiency considerably higher than that for either the National Physical Laboratory or the straight Eiffel type of tunnel. The reason for the power curve showing a sudden increase at the basic speed is because the potentiometer rheostat is connected in at this speed and this absorbs a constant amount of power which is much more than the motor itself absorbs. In Fig. 4 is also shown a curve of the propeller speed plotted against the air speed, that is, the effective propeller slip; and, as would be expected, the slip is constant for all air speeds.

The steadiness of velocity in this wind tunnel compares favorably with that of other tunnels, the maximum variation of the velocity from the mean at any air speed not being greater than 1 per cent at a given point in the tunnel. No manual operation of the controls is necessary during a test, except at long intervals, to compensate for the changing resistance of the motor due to a temperature rise. It was at first planned to construct a speed regulator similar to the one used at Göttingen, but with the proper adjustment of the governor on the generating set, such satisfactory results were obtained that the regulator was found unnecessary. The maxi-

mum variation of wind direction in the throat as determined by a recording yawmeter is ± 0.5 deg., and this variaiton is of such a high period that it does not appreciably affect the readings of the balance.

Balances

The balance mainly used in this wind tunnel is of the modified National Physical Laboratory type, designed and constructed at the Committee's laboratory, a cross-section of which is shown in Fig. 5. The distance from the center of the model to the pivot point on this balance is 54 in., while the distance from the pivot to the end of the weighing arm is 27 in., so that the weights are actually twice as heavy as they are marked. The balance was designed to measure forces on the model up to 50 lb., while the weight of the moving parts was kept down to 46 lb. by the use of aluminum alloys and high-tensile steel. While the National Physical Laboratory type of balance is convenient and satisfactory for small tunnels and low wind speeds, it is felt that an entirely different type of balance must be designed if it is desired to measure forces any larger than 30 or 40 lb., as it is found when the maximum forces are used on this balance that a great amount of trouble is introduced by deflection of the various members and especially by the vibration which is set up when a model is turned to an angle near its burble point. Another objection to the National Physical Laboratory balance for large forces is the heavy weights that must be used; that is, for balancing a weight of 50 lb. on the model, weights to the amount of 100 lb. must be lifted on to the arms, which is very inconvenient when rapid tests are being made. The principal changes besides weights and dimensions which have been made in the original National Physical Laboratory balance are as follows:

(1) A ball-bearing pivot is used in place of the usual conical pivot as the latter gave considerable friction under large loads and also gave trouble through a shifting of its position so that the zero reading was changed during a run
(2) A weighing arm is used for measuring moments instead of the former torsion wire, and in this way lift, drag and pitching moments can be measured simultaneously
(3) The weighing arms are made of light steel tubing, and to prevent deflection they are trussed up with tie-rods, thus greatly diminishing the weight of the arm, while at the same time increasing its stiffness
(4) A pinion is used for turning the head of the balance to make small adjustments more accurately and a prism is used for reflecting the horizontal graduations in a convenient direction
(5) An improved locking device is used on the lower balance tube
(6) The lift is measured very satisfactorily and quickly by a Toledo weightless scale, which allows direct readings to be made

It was found necessary to use a mercury seal to prevent air from passing around the balance spindle into the tunnel, even though the doors in the experimental chamber were closed. This is due to the fact that even with the tightest possible construction there are a number of small leaks about the experimental chamber, the air from which accumulating at the crack around the balance spindle, produces an air flow large enough to introduce a considerable error into the readings of the balance. This seal is made of cast iron and allows a maximum head of mercury of 2 in., the height of the mercury being at all times observable by a glass tube on the outside of the seal. Models are usually supported from the

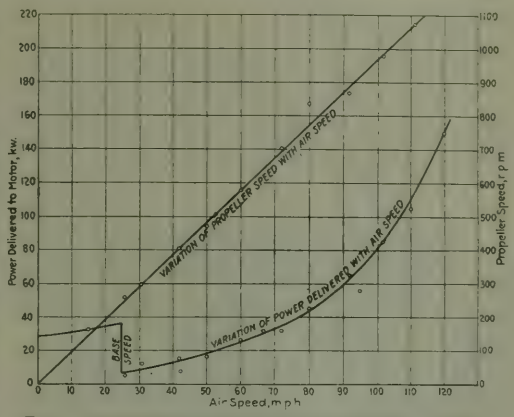

Power Delivered to Motor, kw.
Propeller Speed, r p m
Air Speed, m p h
VARIATION OF PROPELLER SPEED WITH AIR SPEED
VARIATION OF POWER DELIVERED WITH AIR SPEED
BASE SPEED

Fig. 4—Aerodynamic Characteristics of the Wind Tunnel

top of the balance by a tapered steel spindle which is 1 in. in diameter at the base and tapers to 5/16 in. at the top and this is enclosed up to within 2 in. of the model with a thin brass fair-water to reduce the spindle correction to a minimum.[3] As the bending moment in this spindle is very large at high speed and as there is considerable trouble with the model vibrating, a method has been devised by D. L. Bacon for supporting the top of the model rigidly and at the same time reading the

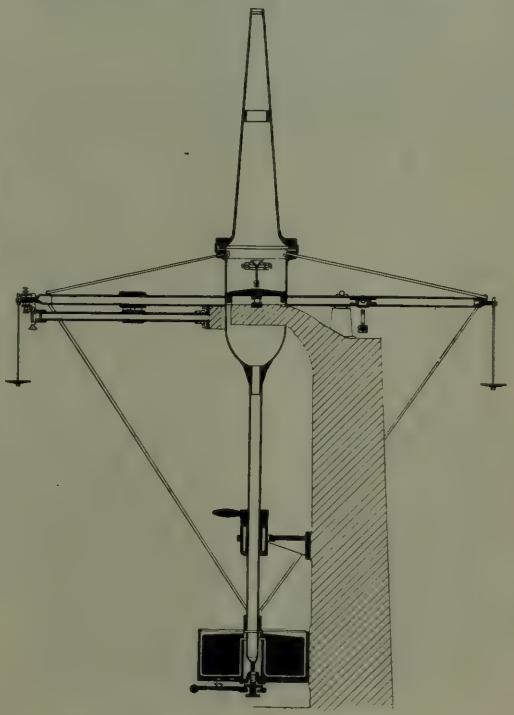


Fig. 5—Sectional View of the Balance Used in the Tunnel

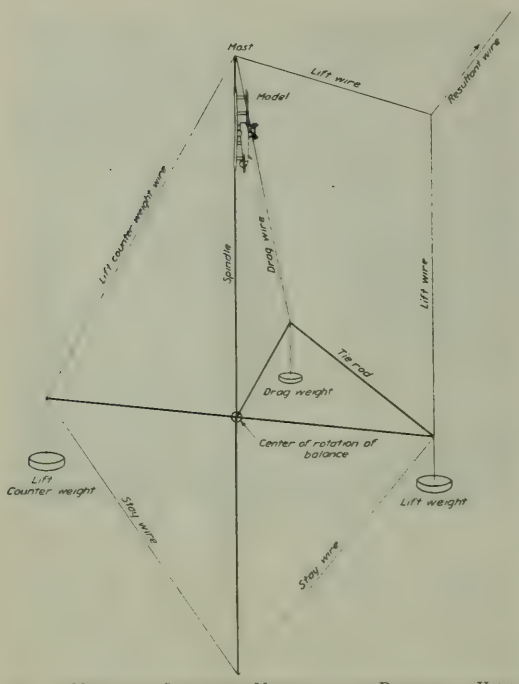


FIG. 6—METHOD OF SUPPORTING MODELS ON THE BALANCE AT HIGH SPEED

forces with accuracy and great rapidity on the balance.

This method is shown in Fig. 6 and consists of a set of small wires, one extending from the top of the model, one from the lifting arm of the balance and a diagonal to the top of the experimental chamber, the direction of this diagonal being such that if it were projected downward it would pass exactly through the center of rotation of the moving parts of the balance. It is also necessary that the plane of these wires shall be exactly in the plane of the spindle and the lift arm so that there will be no component of lift transferred to the drag arm; and this is done by carefully adjusting the top of the diagonal wire until a force on the model in the direction of the lift plane will have no effect upon the reading of the drag arm. The same method could be used on the drag arm but as the forces are not so great it was found sufficient to run a diagonal wire directly down to the end of the arm. These wires pass through small holes in the tunnel walls which are large enough to allow the free play of the tunnel wires and yet due to the air-tight experimental chamber there is very little air passing through them. By this method it has been possible to test a 1/24 size model of the Curtiss JN-4 up to 100 m.p.h. without excessive vibration or deflection and this speed was the limit only because the model itself, even though made of metal, was not sufficiently rigid to stand a heavier load.

As it is believed that the important development in aeronautics of the future centers about the internal'y braced wing, the Committee's policy is to conduct extensive researches on this type of airfoil. The National Physical Laboratory type of balance is unfortunately unsuited to tests of this nature, especially where the wings are tapered down to a thin section at the tip, as it is practically impossible to support such a model by a spindle attached to the end of the wing. For this reason it has been necessary to design and construct another type of balance, which supports the wing nearly at its center by wires, as shown in Fig. 7. The lift and drag can be measured on this balance directly, the lift on a Toledo scale and the drag on a small balance connected to the wing by a parallelogram of wires. The center of pressure is determined directly by finding the point about which the wing is in equilibrium when balanced on knife-edges, as shown in Fig. 8. This method is very convenient and accurate and eliminates the large amount of computation which was necessary in finding the center of pressure travel by the usual methods. While this balance does not take the place of the National Physical Laboratory balance for the majority of the tests, still it is a necessity when it is required to support the model by its center and for wings of high aspect ratio where it would be impossible to support them steadily by an end spindle.

SPECIAL APPARATUS

The air speed in the tunnel is originally determined by a pitot tube and the micro-manometer shown in Fig. 9. This manometer can measure a head of water to 0.001 in., which is sufficiently accurate for any work required

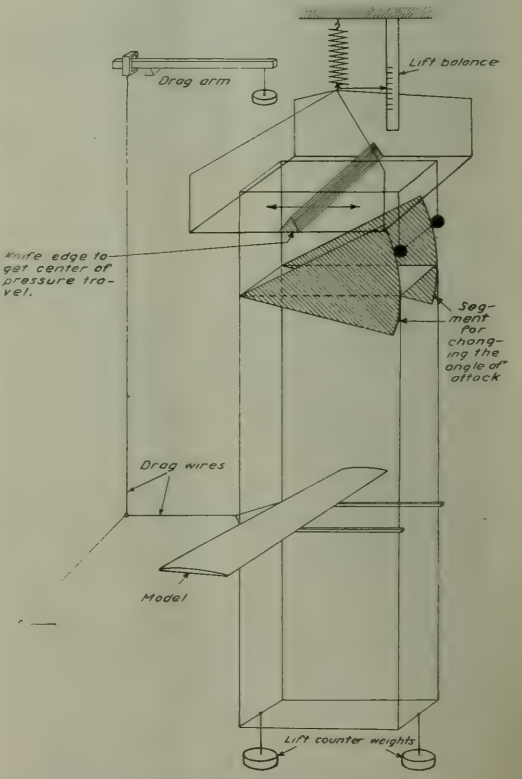


FIG. 7—DIAGRAMMATIC VIEW OF THE WIRE BALANCE

FIG. 8—WIRE BALANCE SHOWING CENTER OF PRESSURE KNIFE-EDGES AND THE SECTOR FOR CHANGING THE ANGLE OF ATTACK

in the wind tunnel, and is very much more convenient than the Chattock gage generally used in wind tunnels, as its sensitivity can be changed by altering the slope of

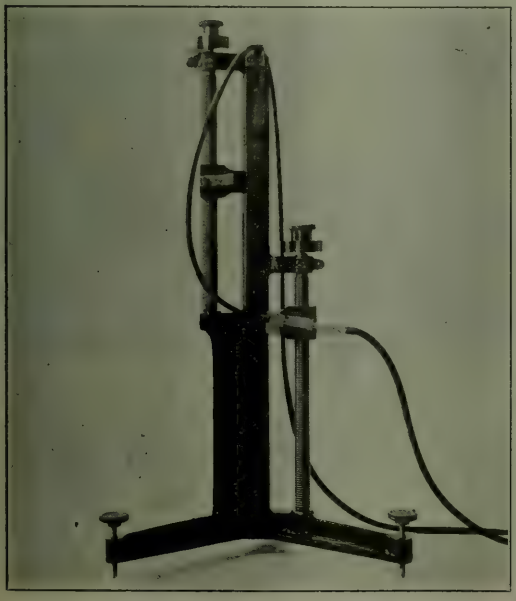


FIG. 9—THE MICRO MANOMETER

the glass tube, and its range can be extended to a head of 18 in. without difficulty.

For usual running, the air speed in the tunnel is determined by the difference between the static pressure in the side of the tunnel and the outside air in the building, this difference in pressure being measured by the manometer shown in Fig. 10. This manometer is arranged so that its sensitivity will be inversely proportional to the head measured so that at the higher speeds where the fluctuations are naturally greater than at the lower speeds, the variations shown by the liquid will be proportionately the same as at the low speed, which is a necessity when running at the highest velocities. This

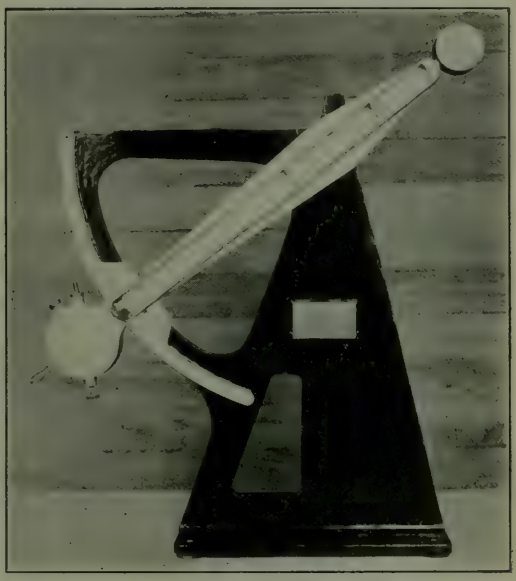


FIG. 10—THE TILTING MANOMETER

gage also obviates the necessity of having a very long inclined tube, which would mean that the meniscus must change its position by several feet, so that the operator would have to stand in different positions for various velocities in the tunnel. This gage is, of course, used as a secondary instrument and is calibrated from the readings of the pitot tube, but actual heads can be easily read on it by measuring the angle of the tube and knowing

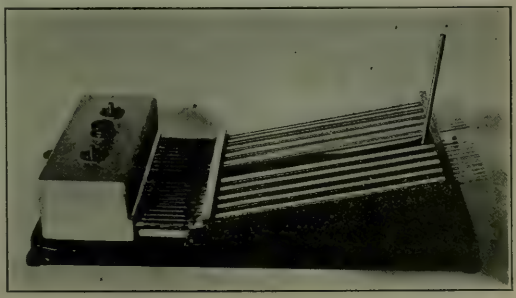


FIG 11—THE MULTIPLE MANOMETER

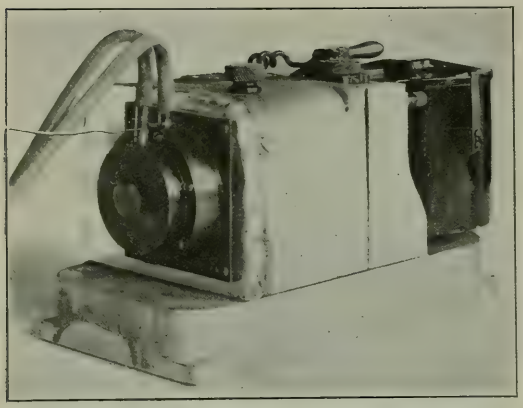


FIG. 12—THE RECORDING AIR SPEED METER

the distance from the center of the reservoir to the meniscus of the liquid.

A multiple manometer is used to a large extent in determining the distribution of pressure over models, and one containing 20 tubes is shown in Fig. 11. The two outside tubes are connected directly to the top of the reservoir so that they will read the height of the liquid at all times, while the other 18 tubes are connected to the pressure holes on the model. The height of the liquid can be adjusted by raising or lowering the reservoir, while the sensitivity can be changed by varying the inclination of the glass tubes.

For the study of fluctuations in velocity and direction in both the model and full-sized tunnel, a number of high-period recording air-speed meters have been constructed, the most recent one being shown in Fig. 12. This instrument was designed to be portable, requiring only a small battery for the light and the motor, and the film is carried in light-tight drums which are used like plate holders. The sensitivity and position of the zero of this gage can be changed easily, making it available for a large number of uses, while its natural period is so high and the friction is so small that it can easily record the highest period fluctuations that will occur in any wind-tunnel work.

Because of the inconvenience and inaccuracy of the old method of aligning wings by attaching a batten to them and then aligning this batten with a parallel line on the floor of the tunnel, a new method is used consisting essentially of a projector which throws a parallel beam of light upon a small plane mirror temporarily attached parallel to the chord of the wing, and this beam of light is reflected back to the cross line of a white target on the wall of the experimental chamber, Fig. 13. To align the model all the operator has to do is to turn the head of the balance until the light spot falls on this cross line, which he can see from any part of the experimental chamber, so that one man can line up a wing to within 0.02 deg. in a few seconds, thus greatly reducing

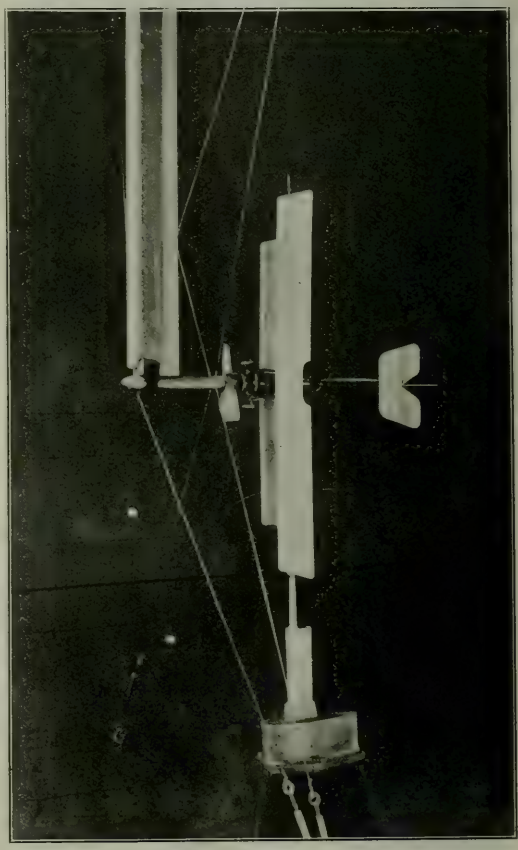


FIG. 14—METHOD OF DETERMINING THE SLIP STREAM EFFECT

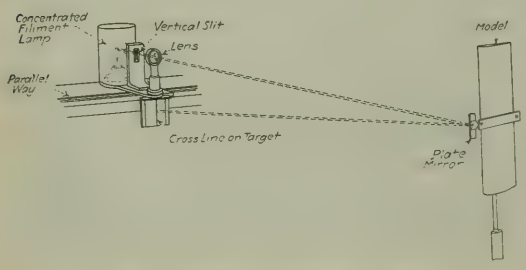


FIG 13—METHOD OF ALIGNING THE WIRES

the time and increasing the accuracy compared with the older methods. This method is also applicable for determining the angular deflection of a wing or model during actual test. The optical method of aligning has been in use for a considerable length of time and has proved very satisfactory, entirely eliminating those errors in alignment which are bound to creep in with the older method, due to unskilled operators or curvature in the batten.

One of the chief causes of dissimilarity between a model test and a free-flight test is the lack of a slipstream in the model, and to produce this effect in the wind tunnel a small propeller is driven before the model by a belt from a high-speed electric motor above the tun-

FIG. 15—A WIND TUNNEL MODEL OF AN AIRPLANE

nel, the propeller being supported by steel wires from the walls of the tunnel as shown in Fig. 14. The wires, the belt and the propeller mounting undoubtedly cause a somewhat different air flow from that occurring in full flight, but this interference is probably very small and at least gives us a much closer approximation of actual conditions than has been obtained before. While it has not been possible as yet to drive a model propeller at a proportional speed to the full-size propeller, it has been possible by using a model with a pitch slightly larger than the full-scale propeller to get a slipstream of the same characteristics as the slipstream in the full-sized machine, which should give identical results as far as the interference of the model is concerned. Work is being carried out on the design of a very small high-pressure turbine to drive the propeller at a higher speed and so that a smaller mounting can be used through reducing the interference.

MODELS

While the models tested in the wind tunnel are, strictly speaking, not a part of the equipment, still those models of such standard form that they are used repeatedly in tests can be considered as such. The Committee has constructed two models of the JN4-H airplane, one of them being the 1/24 scale model illustrated in Fig. 15, which is constructed with the greatest accuracy to reproduce all parts that might affect the air flow, that is, the engine, radiator and wind shields, the only omission being the wires and fittings which can be more accurately calculated than tested. The other model of the same machine has been constructed to 1/15 size for pressure distribution tests on the tail surfaces.

All of the medium or thick wings that are tested in the tunnel are constructed of maple, as this material can be worked with proper precautions to within an error of 0.002 in. The wings are cut upon a special machine shown in Fig. 16, which not only will cut the usual constant-section type, but will also cut wings tapering in plan form and thickness, as, for example, a wing with a depth-to-chord ratio falling off toward the tip as a parabolic function, and at the same time with an elliptical plan form. A much heavier and more precise machine of the same type has been designed for cutting and grinding aluminum or steel wings. Without a machine of this type the Committee's extensive program on thick tapered wings would be impossible because of the great expense of making the models by hand.

The wind-tunnel work of the National Advisory Committee at Langley Field, in contrast to the work of most of the tunnels in this country, is entirely research on the fundamental problems of aeronautics, such as the systematic design of airfoils, the scale effect on models

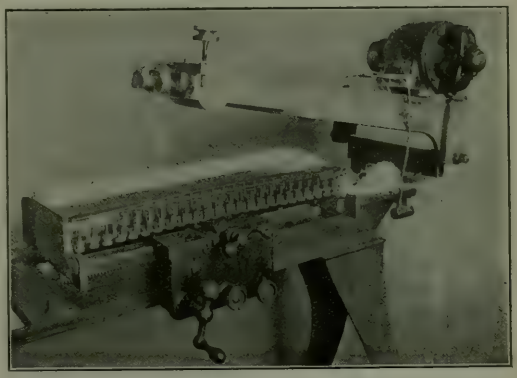


FIG. 16—A SPECIAL MACHINE FOR CUTTING AIRFOILS

and the relation of the stability on models to that in free flight. Fortunately, it is possible to carry this work on most efficiently because of the close cooperation that can be had with the free flight investigations which are being conducted by the Committee at the same time. It is, however, realized that with only one wind tunnel, the various model investigations cannot be carried on simultaneously, and so the work cannot be conducted as rapidly as desired, but it is expected that a second and larger tunnel will be constructed by the Committee in the near future, which will greatly extend the range and amount of investigation possible.

[4]See National Advisory Committee for Aeronautics Report No. 54.

"RICH" MIXTURE FOR STARTING

AN engine does not require a richer mixture for starting up than for slow running, but it does require more gasoline, which is not at all the same thing. For, especially with modern fuels, the constituents that will volatilize at ordinary temperatures are low in quantity and, therefore, only a small proportion of the fuel actually used goes to form the mixture. The rest, under the conditions of low velocity and consequently low atomization then obtaining in the induction system, simply falls out of suspension and becomes deposited. It usually lies in little pools until the throttle is more widely open, when the engine perforce drinks more than is good for it, and chokes and gasps.

Much the same unfortunate set of circumstances occurs with the engine "idling" when cold, that is, very much more gasoline is required for slow running with a cold engine than when the engine is hot. Many people boast that their engine starts and gets away well from cold, and requires no warming up. So it does, at a price. It is not possible, with the present type of slow-running devices, to have economical slow running when hot with the same setting that gives an easy start and idling when cold, and therefore a compromise setting is almost universal in which starting is somewhat difficult, and slow running when the engine has warmed up is extravagant.—*The Car.*

Engineering as a Profession and the Value of an Engineering Education[1]

By Henry M. Crane[2]

THE profession of engineering in some of its branches is one of the oldest recorded in history. This statement which is a rather sweeping one requires some explanation. Engineering can well be divided into two general classes based on certain broad principles rather than into the many divisions commonly used in which the classification is on a purely industrial basis. There are two broad divisions of engineering which cover practically all forms of engineering activity. These are research engineering and constructive or creative engineering. In the former division are included the work of the scientist, the work of the investigator and the work of the inventor; in the latter the work of those whose task it is to assemble the knowledge gained in research during all time and to use such knowledge in the creation of things of value to all the people, such as the simple telephone receiver or the complicated telephone plant of a great city, or in planning for the production of the articles in question.

Research engineering is the foundation upon which the great fabric of constructive engineering must rest; it is the work of the research engineer that was recorded many hundreds of years ago. On the other hand, constructive or creative engineering has grown to its present clearly defined position during the last 100 years. Its development has followed closely the lines of industrial evolution for reasons that are plain. In the earliest days industry was purely personal, as in the making of stone implements or of armor. It was entirely natural that the maker should also design his product. Later on such activities as the building of ships required a community of effort which had appeared from time to time theretofore in the construction of buildings or bridges. In almost every case, however, the director of the work was likewise the one who determined its form.

The Development of Industry

Until about 100 years ago industry was still relatively in an undeveloped condition, largely on account of the absence of any great prime-mover. It is true that wind and waterpower were both used in a small way in various operations, but the coming of the steam engine was needed to start the growth that has resulted in the highly organized industrial world of today. The steam engine by itself could meet only in a limited way the requirements of a great industrial expansion. Coupled with the necessary steam boiler it could not be operated economically except in units of moderate size, owing to the lack of suitable means for distributing the power produced. Electric transmission finally solved this problem not only for the steam engine but for the immense available waterpower previously going almost entirely to waste. The discovery of petroleum and the subsequent development of the internal-combustion engine capable of being operated by anyone of average intelligence and of furnishing power economically in units of the smallest size broadened still further the field of industrial possibilities.

The effect of industrial growth and concentration was an increasing specialization not only in the duties of the directing minds. Under this pressure there came finally an almost complete separation between the work of planning for and the work of directing the production. The work of planning for production, either in designing the article to be produced or in laying out the method of production, has now become the province of the constructive or creative engineer. In the smaller shops the duties of planning for and of directing production are still sometimes combined with those of actual production or operation, but such cases represent a minor proportion of the total. The reason for this condition is fairly obvious; the work of designing or planning requires special training, a broad understanding of the results of world-wide and age-long research in the field to be covered and a constant study of current research. This knowledge cannot be obtained and properly assimilated except under conditions permitting almost undivided attention to the subject in hand and excluding the necessity of giving attention to the multifarious questions arising in the executive management of production or operation.

It is certainly easy to recognize the effect that this development has had on the opportunities for the trained engineer. One hundred years ago a few laboratories or an occasional observatory presented themselves as possible places of employment. Today there is not a single industry that does not make use of the services of the engineer in some way. Even the farmer is finally succumbing to the mechanical operation of the farm. In most industries the engineer has to do not only with the original design of apparatus but also with the methods of production and subsequently with the operation in service.

The Engineer's Place in Industry

Furthermore, the engineer is only beginning to come into his own. Originally he was more or less of an assistant to the operating head and was looked down upon accordingly. He was considered to be impractical and not to be depended upon in the daily routine. This was perhaps more or less natural in view of the lack of understanding regarding the two very distinct engineering functions described at the beginning of this paper. In the early days almost the only men called engineers were those having research training and the research point of view. It is not surprising that these men were not successful in carrying any great responsibility in creative engineering work. Engineering ability of the creative kind is nothing but trained common-sense coupled with a certain fund of ready knowledge and the more important understanding of where to go to get any particular information required at any given time. That men having this ability are capable of successfully carrying out most important tasks has been amply demonstrated in recent years.

In any industry of the manufacturing type there are three main divisions outside of the general executive and financial supervision; these are engineering, production and selling. These functions must all be carried out with equal ability for the greatest possible general success of the whole undertaking. In many cases the engineering has been given the least weight of the three. While this has often been caused by some weakness in the engineering personnel, it has at other times been the result of some of the engineering functions having been taken over by one or both of the other divisions, with a consequent weakening of the responsibility of the engineering division and a very natural loss in efficiency.

The assumption sometimes made by the production department that the engineer cannot be expected to design with ease of production in mind is an invitation to the engineering department to disregard this very important feature of design entirely. Here is demonstrated one of the worst faults of the modern industrial system when organization and specialization are carried to extremes. It is only when the engineer in designing any piece of apparatus keeps con-

(*Concluded on page* 508)

[1] Reprinted from the *Yale Daily News*.
[2] M.S.A.E.—Consulting engineer, New York City.

Research the Bond Between the University and Industry

By A. E. White[1]

Detroit Section Paper

RESEARCH has been accepted and accredited as a function of our schools and colleges since their very establishment. Even in the days when Latin, Greek, philosophy and theology were the main subjects in the curriculum, it was duly recognized that research in these fields into nooks and crannies still unknown was a fundamental and necessary function for the instructor. Thus, research is no new and untried thing; that which is new is the modern concept of it. The present concept is that in our universities and colleges greater attention should be directed to those phases of research which will mean greater employment and greater prosperity of the people. There are those who feel that such a concept is not in keeping with the best traditions of our schools. They feel that our research, whether in the philosophical or natural sciences, should be abstract or intangible. They feel that the possible sordid effect of money may cause attempts to use research for the selfish benefit of a few. They hold themselves aloof from matters of an industrial character. They realize that their training, their very life-work, has necessarily kept them out of contact with industry and its needs. In their ignorance they are willing to view research in the same light as it was viewed by our forefathers. They are willing to profit by our material advances but unwilling that our universities should do their share in these advances.

To whom do we owe the developments in steam, in electric transportation, the electric light, modern sanitary equipment, the automobile and the numerous other things which make life easier and more pleasant? Would we replace the modern Pullman or the automobile with the leather-sprung coach; would we return to the oaken bucket in preference to the modern bathroom fixtures, or to candles instead of electric lights? It is true that college men have had their share in these developments; the distinction is that this has not been as graduates doing such work in close contact with the university, but as men divorced from the University in large measure, if not completely. It is true that to Charles P. Brush we owe much of the development of electric lighting, and that to Howard E. Coffin and others we owe the modern automobile; both men are alumni of the University of Michigan, but who associates this University with the development of electric lighting and automobiles? I have no quarrel with those who believe that a university should confine itself closely to abstract research. I believe we should encourage work of that type in every possible way. Through it we widen our knowledge, we add to our culture and, in the field of natural science, we work toward laws that are at the foundation of science. I trust that as departments of engineering research develop in universities they will have funds available for work of this type and can carry on such research work as they desire in as great magnitude as the work warrants.

Hesitation to Encourage Research

The mistake that has been made in the past is that undue reticence has been displayed by those in authority at our institutions of learning in encouraging industrial and engineering research. This reticence is possibly a relic of the opposition that engineering education has encountered since the days of its inception. It was only after overcoming much opposition that Rensselaer Polytechnic Institute was established in 1837. It was felt for a long time by many of the leading educators of that period that the training at the school was too practical and not in keeping with the traditions of higher education. Yet today we have no educators of moment who would make such a charge against our modern engineering schools and colleges. Have not many of us as educators gone only half way? In taking a leading part in engineering education but not in engineering research, have we not fulfilled only half our mission? Should we neglect engineering research merely because it comes close to the material concerns of mankind which have great possibilities for adding to our efficiency and comfort? In an attempt to meet the old-time classical viewpoint on research, have we not neglected the modern engineering viewpoint? The neglect is readily explained. It came about because of the very rapid increase in attendance at our engineering schools and colleges; the various members of our faculties had little time or strength to devote to problems other than those of teaching. The money available was consumed in the procurement of buildings and apparatus for instructional purposes.

To illustrate present-day conditions I will state some facts concerning the University of Michigan. There was available for the college year 1920-21 for new equipment the sum of $20,000. Is it realized that this sum must be distributed among the departments of civil, mechanical, electrical, chemical, marine and aeronautical engineering, and architecture? Is it realized that in chemical engineering we attempt to be conversant with inorganic technology, including work in salts and sugars and involving evaporation in all of its various ramifications; with organic technology, including work in dyes, oils and engine fuels; with metallurgy, including iron and steel, copper, brass and bronze; and with fuels, including gas manufacture and coking practice? Do those who have been given opportunities to spend or to authorize the expenditure of sums ranging from a few thousand to hundreds of thousands of dollars for the purpose of solving a given problem imagine that much work of real value can be produced under such limitations? This statement involves no charge against university authorities relative to an improper assignment of funds, because the engineering college is given its pro rata sum; but it does

[1]Director, department of industrial research, University of Michigan, Ann Arbor, Mich.

imply one of two things. Either we have looked at matters from an utterly inadequate angle, or those who are in the industries have spent money on research like drunken sailors. I believe both conditions exist. It will be to the advantage of industry from all angles if the universities and the research work in our various industrial centers can be brought into closer contact.

This very limitation of funds has seriously hampered the mission of many of our teachers. They attack problems uncomplainingly with equipment that seriously handicaps rapidity of solution. Those who are in the industries would no more think of undertaking tests with inadequate equipment and facilities than they would think of turning Lake Erie salt by pumping into the lake the brine from our salt wells. Yet our teachers carry on their work as best they can, under most extraordinary handicaps. Is it any wonder that results are obtained only slowly? Nevertheless our universities are our most consistent and continuous producers of research. Beyond question, the magnitude of research at industrial plants has far outstripped that at our schools. Where universities spend a thousand dollars, industry spends a hundred thousand. Where industry has every facility of equipment and chemists, draftsmen, engineers, clerks and stenographers, university professors are compelled to do everything themselves. Where a university must take down and replace apparatus because of lack of space, industry builds a special laboratory if necessary. Proper facilities for research at our universities must be provided, if the grade of men necessary for the proper conduct of industrial laboratories is to be forthcoming. It is believed that this handwriting on the wall has been seen and that a day will break shortly when the universities and the industries will be closely allied with respect to research.

Universities are not totally to blame for the present lack of cooperation. There has been and still is a belief in some lines of manufacturing that secret research will develop products of great value. Research that is cooperative with respect to industries of an allied type and with respect to close contact with institutions of learning is the development of the day. Cooperation in this manner means a free interchange of information. It means freeing industry from the fetters of belief in the power of patents and in the value of secret processes. These two bogies have been most powerful agents in preventing rational cooperation. Business achievement is more a matter of business administration and economics than of patents. Can one of our automobile companies attribute its success to patents or are any furniture factories, stove foundries or iron, steel, brass and copper plants dependent for their success upon patents? To one company that attributes its prosperity to patents there are hundreds that cannot make such a claim. Should companies refuse to cooperate with one another and with a university merely because this may entail a surrender of patent possibilities and the control on matters of publicity? Would not the saving resulting from such cooperation offset in practically every case the benefits obtained through secrecy? Even if matters of industrial success depend upon secrecy, including patent privileges and deferred publication, is it expedient, proper or wise that a State institution should be a party to such a course? Should a university lay itself open to possible charges of serving private interests? It would be entirely proper to issue patents in the name of the public, so that the unscrupulous would be prevented from collecting blackmail or deriving improper benefit from something that had been worked out for the benefit of the public.

The Situation in Michigan

Before proceeding to a statement of the proposed work of the department of engineering research of the University of Michigan, let us picture to ourselves the industrial situation in the State. In 1899 Michigan was the ninth State with reference to the value of its manufactured products. In 1904 it had crept to eighth place and in 1914 it occupied the seventh place. The census figures for 1919 are not yet available, but it is safe to say that Michigan has not slipped backward and in all probability is in fifth place, being led by only New York, Pennsylvania, Illinois and Ohio. Detroit has had a still more remarkable growth, rising from sixteenth place among the cities of the land in 1899, to fourth place in 1919. Unfortunately, no detailed figures are available for conditions since 1914. Figures for 1914 are given merely to enable one to draw a mental picture of the type of industries in Michigan, not with any idea of giving a view of the numerical scope of these industries. In 1914 there were six industries in which Michigan took first rank: automobiles, druggists' preparations, refrigerators, wooden goods not elsewhere specified, showcases and airplanes. There were five industries in which Michigan had second rank: furniture, stoves, salt, wood distillation and wall plaster. There were nine industries in which it stood third, seven in which it stood fourth and ten in which it stood fifth. Based upon the value of the product, the automobile industry for 1914 was credited with $398,289,022. By 1919 this had grown to an estimated yearly value of $1,393,000,000. Detroit's quota of this amount is believed to be about 63 per cent. Foundry and machine-shop products, lumber and timber products and furniture, with a value in 1914 of something over $30,000,000 individually, will doubtless show a collective value for 1919 of over $350,000,000. Four other industries, flour and grist mills, tanned, curried and finished leather, paper and wood pulp, and slaughtering and meat packing, produced goods individually to a value of over $20,000,000 in 1914. There were 11 industries with a value of product in 1914 of over $10,000,000 individually: lumber and planing-mill products not included in planing mills connected with sawmills; brass, bronze and copper products; food preparations not elsewhere specified; malt liquors; chemicals; butter; steam, gas and water engines; printing, publishing, newspapers and periodicals; tobacco, cigars and cigarettes; druggists' preparations and illuminating and heating gas. There were 11 industries with a value of product of over $5,000,000 each, 27 with a value of over $2,000,000, 21 with a value of over $1,000,000, 18 with a value of over $500,000 and 24 with a value of over $250,000. The total value of Michigan's manufactured products in 1914 is given as $1,086,000,000. The estimated value for 1920 is close to $3,000,000,000.

During the war it was estimated that 2½ per cent of the value of the finished product was chargeable as the cost of inspection. Should we accept this percentage figure for inspection work and add to it one of similar amount for research, we would have a sum total of $150,000,000 based on a $3,000,000,000 valuation of the manufactured products for 1920, of which $75,000,000 would be for inspection and $75,000,000 for research. If these figures seem too high, go back to your industrial plant and learn the real facts regarding inspection costs; include not only the labor of inspection but the labor lost on work

which proved to be defective before the final assembly; include lost materials, lost supplies such as fuel and lost use of equipment. If $75,000,000 looks like a big sum for research, let us realize that we are taking a State-wide view of the situation. There are men here tonight from companies that have not hesitated to spend $500,000 a year on research. It would take only 150 such companies to make $75,000,000 and when we realize that the number of good-sized industrial organizations in this State runs up into the thousands this sum when distributed shrinks into insignificance.

With this picture before us it is not hard to realize what should be the position of the department of engineering research in its relation to the industries. It should become the research center for the industries. Each main group of industries should band together and problems that are common to all should be worked out in a common center. The University places its facilities at your disposal. To be sure they will be far from adequate when industries fully awaken to what has been placed at their disposal; but there is a basis and beyond that increased facilities imply nothing but buildings and equipment. If these must be procured, it is much cheaper to procure them jointly than separately.

Do you say that we have no problems? I expect that statement from sections which are dying from dry-rot, but not from a State which has shown itself to be as vigorous and progressive as Michigan. The minute we cease to have problems we cease to be alive; may such a day never come. Do you say that we have no problems of a joint character? There again I say that those industries of a similar type that cannot ally themselves with one another to the extent of finding problems of a joint character are not truly representative. They are not the type we desire in this State. They either lack that spirit of cooperation so essential to present-day progress or have become decadent and will not long withstand the continual battering of modern business. Do you say that we are not sure whether we will get results, since we have little choice in the selection of the men who will do the work or the methods of attack that will be pursued in an attempt to solve the problem? I answer that the University will be only too glad to cooperate to find the right man or men for the given problem or problems. Men who will be assigned to problems will be chosen on the basis of fitness, irrespective of whether they are now connected with the University. As a matter of fact, there is not now a man on the faculty who is not carrying a full schedule. This means that the men who shall handle these problems must come from the outside or, if they are chosen from within, we must find men to take the present teaching positions.

Some concern has been expressed that the department of engineering research would develop into a testing bureau. No fear need be entertained on that score unless the industries themselves demand such a laboratory and will procure facilities so that such a laboratory can function. At present, no funds are available for the maintenance of a staff necessary for such a department and there is no building for housing such a laboratory. As a rule, most companies have a laboratory of their own for such work and those which have not can send their routine work to laboratories established for just such a purpose, they being in a position to render the service at a much lower cost than it could be rendered at the University under present conditions.

It is believed that the department of engineering research at the University of Michigan can be of distinct service and value to the industries of the State through the channels of centralized research. It is recommended that the industries of the State having interests closely allied join together and that there be formed in each group a research committee to confer with the director of the department of engineering research on matters relating to problems and policies. Included in this discussion there should come up matters relating to costs and details regarding how the problem or problems are to be approached, with respect to who is to take charge, and other things of a pertinent character. The committee should then report its findings to the interests represented, unless otherwise empowered, and procure from them authorization to proceed with the work. In the case of an individual industry, the same general procedure should be followed.

The University has already pointed out to the industries that, although it is desirous of doing everything in its power to be of service, it cannot assume the cost of the investigation and researches beyond a very nominal figure. The facilities of the University library are at the disposal of the industries. This library is among the largest in the country and is especially strong in technical books and periodicals. No research on a given subject should be undertaken prior to a thorough study of the literature on that subject. Often such a search saves thousands of dollars. On Feb. 1, 1921, the industries of the State were advised of this service, but the resources of the library in this respect have not yet been scratched. The industries of the State cannot afford to make as little use of libraries in the future as they have made in the past. Requests for service can be made to the librarian or the director of the department of engineering research. This service includes the loan of books and periodicals and, at a nominal charge, abstracts, bibliographical lists and translations. The service further includes the use of buildings and parts of buildings when not in demand for instruction purposes. At present, because of the large enrollment, there is no space that can be set aside permanently for this work. For instance, one of the department heads of the University has but one-half an office; if given the same facilities accorded the members of the faculty at Columbia University and the Massachusetts Institute of Technology, he would have two private laboratories and a private office. Further, the equipment and apparatus, when not employed for instructional purpose, are placed at the disposal of the industries at fees sufficient to cover the cost of repairs, renewals and replacement.

Little thought is required to appreciate how necessary is the passage of the budget now before the State legislature if the University is to serve the industries to advantage. The passage of this budget in its entirety is essential, for there is not a single item that can be cut without seriously hampering the work of the University. We are engineers and are interested primarily in the engineering requests, yet the other items are of equal importance. In this budget $1,500,000 is requested for an engineering laboratory. It is vitally necessary that this sum be granted since it will provide increased space for the college of engineering and for the department of engineering research. Considering that today the University has no greatly augmented facilities for engineering training and research over what it had in 1910, that the student body in this college is double what it was then, with good prospect of being trebled by 1930, and that the State has leaped into a commanding position from an industrial standpoint, with the value of its

products increased from $685,109,169 in 1909 to approximately $3,000,000,000 in 1920, is it not time to request increased and improved facilities to train men for the industries and also for research?

The department of engineering research has been established for the purpose of assisting the industries in such proper ways as lie within its powers. It places at the disposal of the industries its library and available laboratory space and equipment. The industry or industries requesting service are to pay labor charges and a nominal fee for administrative expense and the use of equipment and provide special equipment. As a State institution, the University cannot grant special privileges. Therefore work on which patents or privileges with regard to matters of publicity are desired cannot be accepted. It is recommended that problems of a joint character be placed before the department of engineering research for solution. It is believed that by cooperative alliance large sums can be saved each company. The present day is unquestionably one of cooperation, economy and a strong belief in the value of properly conducted research. The department of engineering research is founded upon this basis, trusting that it shall be of great service to the industries of the State, and through them to the State proper, and that it shall be credited with duly laboring for the cause of true science of which research is the chief if not the only servant.

The Discussion

GEORGE E. GODDARD:—Research certainly is applicable to many different materials that are used in automobile construction. No doubt each company spends much time and money in research work during a year's time. If read by some of the manufacturers themselves, this paper should prove of great assistance to the automotive industry. What way is there in which automotive engineers as a body can help this research work along? It is undoubtedly a worthy cause. Many industries of the State are allied very closely to the automobile industry and many different materials go to make up a motor car, considering all the accessories. Some of the accessory manufacturers have problems regarding materials. All these companies should be able to receive some help through the facilities of such a research department as the University has at the disposal of the industry. Even though these facilities are such that many in the industry would not be likely to have them at their disposal, there is undoubtedly much there that the automotive industry has not availed itself of.

CHAIRMAN HOWARD A. COFFIN:—I have listened with much interest to Professor White's paper. I believe the industries of Detroit do not realize how much of an asset they have in the University of Michigan. We think of the University as an institution that is set apart, a sort of cloistered place where a fellow drops out of life for 4 years and studies. I think that few of us appreciate how vital the University is in the life of the City of Detroit and the State of Michigan. I think few of the industries in Detroit realize how much of real definite value there is to them in the equipment, the personnel equipment particularly, of the University. We should make more use of the University.

PROF. A. E. WHITE:—With regard to the matter of organization, we have had two fundamental committees in the department of engineering research. One is known as the administration committee; it is attempting to work out the policies of the department from the University's viewpoint. The other is a committee that we call our advisory board; it consists of 100 men, all of whom are leading men of the State, having to do with the mapping out of the policies of the various companies with which they are connected. This committee was selected in such a way that every important part of the State and essential industry should have representation. The department of research was formally established in October, 1920. It is intended that this committee, which has itself appointed an executive committee of 17 members, eight or nine of whom are from Detroit, will convene early in April. That committee of 17 will be requested to appoint subcommittees from each of the essential industries in the State, which will confer with the director with reference to working out close cooperation between the University and the industries.

PROF. W. E. LAY:—As one of the other professors of the University of Michigan, I would like to state that research at the University may be slightly different from what it should be in a factory. The men theoretically should not be in such a hurry to get things out and when given problems ought to feel at the time that they are to follow a problem out in all its details and thresh it out completely. Practically, that is not true with research as it now stands at the University. The men who are attempting any research have too many duties in respect to instruction and other regular work to go as far into details as they would like.

The very atmosphere of the place is different from that of industrial plants. It is suggestive of complete and careful investigation with no element of hurry in it. The University does not require great speed in research. If any research should be done at a university in connection with the automotive industry, it can be conceded that the University of Michigan should do the most of it. Within a radius of 100 to 150 miles of this University are a number of cities which include the greater part of the automotive factories and organizations. No other university is so well situated. The taxes which the manufacturers pay go to keep up this University.

WALTER T. FISHLEIGH:—I agree with everything that has been said on this question, and then I begin to think just exactly what does all that mean in connection with our work. For example, there are many things of a universal nature that we would all like to know. We would all like to get a tire that has all the advantages of an air tire, but that is puncture-proof, is not made out of rubber and would cost about one-fifth as much as present tires and give us 10 times the mileage.

There are 100 or more such problems of universal interest. We work a long time on some problem and get a good idea about it, then this matter of patents arises and we find that the idea is several years late. We need to solve problems of that sort. But practically it is a matter that must be taken up slowly and cooperation is not coming in a minute. I cannot visualize all the details, but I think there are some things that can be worked out. The big problems that we are interested in are very expensive in the main. Different companies are not always interested in the same things at the same time. The problems are not Michigan's problems alone; they pertain to all the States. Many such problems go to the Bureau of Standards at Washington.

We have in our factory today some brake problems. Perhaps some other firms care nothing about brakes. In other particulars our company may be far ahead, on light-weight construction and some other things; so, we are not all interested at the same time. Except for problems that are vital to us today, we are not interested in

research, but I believe there are some fundamental problems where the University can take a big step forward.

PROFESSOR WHITE:—I believe that the problems which will be selected are those which the industry will choose. That is one of the hopeful things with regard to the whole situation; industry is to select the problems on which there shall be cooperation. I think we have the manufacturers interested in this department.

Inadequate funds have necessitated our looking at matters in a small way; and yet I believe that with the cooperation and the power to give the funds that are within the manufacturers' hands, and the ability of automotive engineers to suggest the problems, we have a more hopeful situation than we have had in years. The Regents, through the appointment of a director of research at the University, have provided the necessary machinery for approaching the companies of the industry with reference to cooperation. I want the industries to feel that any investigations that we undertake are their own investigations. I want them to have on the job that man or that corps of men in whom they have confidence to direct the work. Those men may come either from the University or from outside of it. Nothing has been said with regard to whether we could accept work in which persons or firms residing without the State would share the benefit, but I believe the fact that we accept students from without the State constitutes a precedent. I think that if an association requested that research work be done, and a large number of the firms in the association were resident in Michigan, it would be entirely proper to accept the work.

A. I. STEVENS:—The problem of pitting and lumping in a minute way of black baking enamel, which is used so largely in the automobile industry as to be almost of universal interest, has been investigated by the National Paint, Oil and Varnish Association and referred to the various chemical laboratories. It is most discouraging to the enamel or japan manufacturer to fill a 5000 to 10,000-gal. tank, assured that the chemical ingredients, the heat and everything else known are correct so far as possible, and then find that the whole tankful must be scrapped, without being able to tell why. It might be considered a weakness that such a thing could exist, but it is not. All varnish houses have the same experience. Considering the large amount of baking-enamel material used, the trouble is well worth investigating.

MR. GODDARD:—I am acquainted with some of the troubles with enamel. One feature of enamel that has to be considered is the specific gravity. It is a big problem and will become more and more important. The varnish situation is rather interesting to all of us. Varnish workers have been trying to find ways to flow varnish in a way similar to that in which enamel is flowed. I believe some of them have accomplished results which they were forced by circumstances to perfect in a short space of time. I give that as an example because it shows the renewed interest in a subject in which it may be necessary to perfect the practice; something of which there was a fair knowledge in a general way, but which required development within a short time.

M. H. WELLS:—What benefit would the engineer himself derive from research financed by an organization or association? How about the various ideas originating in the mind of the individual engineer? He cannot develop his ideas; he has not the money. His company has not, but his idea would probably be very beneficial to the entire trade. For example, I know of an engineer who has an idea for the prevention of crankcase oil dilution. He believed he had the right theory, but he simply had to drop it. Could a bureau or a fund be established whereby such individual engineers could present their ideas and have someone carry them out?

PROFESSOR WHITE:—I am hoping that we shall have various committees formed. For instance, we will have an automobile committee. I expect that this committee, in turn, will appoint several committees to handle various phases of the work. I know that the problem would be attacked at the University. If the association felt that the problem was worth while, it would make funds available so that it might be handled. The question of whether it would be handled would be left entirely to the committee appointed by the executives of the companies.

U. G. THOMAS:—It seems to me that this research department will find it difficult to please everybody and really get anywhere. On the tool-life question, after the proper research has been made, how will the manufacturer be told how to utilize that research? In different factories, a drill might be heated in a hand forge, an electric forge or a furnace; the oil that it is dipped in may not be the proper kind to produce the correct temper. Brake-lining has been mentioned, from the production standpoint; I mention tool life from the production standpoint. One car uses a 10-in. brake lining, 2 in. wide and ¼ in. thick; another car has a 14-in brake lining, 3 in. wide and ½ in. thick. One car has external and internal brakes; the other has both internal. How are we to arrive at what all of them want? We have many S.A.E. Standards that are being universally used; they are fine and can be universally used. When this research department at the University gets results on the practical points, it will be of vital interest to the manufacturer, regardless of what the individual engineer has to say about it.

PROFESSOR WHITE:—We must draw the line at problems that are of interest to only one individual company. In most cases such problems can be solved at the individual plant. Then we must distinguish between working out a procedure and determining whether that procedure is the right one in an individual plant. To illustrate, I had called to my attention the fact that certain boiler tubes were developing brittleness. Some tests that were made indicated that if those tubes were heated to a light yellow, the brittleness would be removed. The company was advised, but after two attempts the tubes were exactly as brittle as before because they did not heat them hot enough. After a tube was brought up to a light yellow heat under my supervision, it became as tough as a new tube. If we should find out the proper method of heat-treating tool steel and give that method, I will agree that in many plants we would still encounter trouble with tool steels, because of failure to follow the directions. I feel that if manufacturers can be advised to a greater extent than they are now with regard to what should be done, they will be in a better position to control their workmen and will cut down the number of troubles that they have, although we cannot expect that all their troubles will be eliminated.

PROFESSOR LAY:—It appears that all the advantage that might come from this research department would accrue to the manufacturer, but this is not wholly true. If a man has no interest in research and is attempting to teach engineering, he will soon simply die of dry-rot. I believe that those of us who are teaching will reap a very large benefit from this research work. The men whom we teach, and will later go into your organizations, will also reap the benefit.

The Engineer's Place in the Industry

FOLLOWING the regular business session at the Annual Meeting, Jan. 12, 1921, the subject of the Engineer's Place in the Automotive Industry was presented in addresses delivered by H. M. Crane, H. W. Alden, F. E. Moskovics, J. G. Utz and J. G. Vincent. The remarks of the different speakers are printed below substantially as delivered.

ADDRESS OF HENRY M. CRANE

WHEN I began thinking about the origin of engineering as a profession, I was much surprised to realize that it is of extremely recent growth. In making this statement, I draw the line possibly in an arbitrary manner between the experimenter, the investigator in chemistry or physics or allied lines, and the men who take the results of such research work and put them in form for the use of all the people. I think that this is a very reasonable line to draw. A misunderstanding has existed among many of the executives in the automotive industry, especially its financial men, as to the radical difference between scientific experiment and engineering practice, which are of equal importance. This has caused much friction and possibly retarded the progress of the engineer toward a place in the industry equal to that occupied by the selling and production departments.

If we look back only 100 years, we see the shipyard workers fabricating ships designed by the builders; the men who actually produced the ships decided what they would be, in both form and structure. Not 15 years ago, in the coach-building end of our own industry, there were many coach-shops in which the drawings were nothing but the simplest kind of sketches. These were used only as a general outline for the workmen, who took the material and formed it into the desired shapes themselves, guided by their long experience. I believe that such a form of manufacture has many good points; the close connection between the design and the manufacture produced very practical articles. The two departments practically were one. The articles possibly might be criticized because of theoretical considerations, but the men who were successful became successful because what they produced actually operated and gave service.

The Era of Specialization

As industry and the individual industries became greater in size, we started on an era of specialization. I imagine that the beginning of the engineering profession was largely in the drafting-room, where the then engineers put down the ideas of the boss as a matter of record, for future reference or to be transmitted to the workmen. The activities of these engineers, who were then engineers in name only, if at all, continually broadened as time went on until in many cases the designing came entirely under their direction. However, in the automotive industry this designing was largely the primary stage of production, because no design was sacred from the hands of the production man. I do not take the attitude that designs should have been sacred from the hands of the production man; I simply am making a statement which we all recognize to be true.

Those who have followed me so far will feel, with me, that the engineer has reached a milestone in his progress, but that he has still a considerable distance to go. The engineer and the shop and the sales department in many of our companies are too widely separated at present; in other words, we have reached the extreme of specialization. In the mind of some men the engineer is not supposed to know about what a salable automobile should be, but should take his directions from the sales department; he is not supposed to know how an automobile can be built in an economical manner, but should take his information from the shop. The shop, likewise, is not supposed to know what constitutes a correctly designed automobile, but is supposed to take its information from the engineers. It is evident to me that a system rigidly conducted on those lines has very little chance in competition with the old system of 100 years ago in which the knowledge was combined in one executive, in the final efficient production of the best article. I do not wish to be understood as saying that we can go back to the conditions of 100 years ago; we cannot. No man living is big enough, mentally, working the hours per day that a human being can work, to combine in himself all of the various forms of knowledge required in the operation of a large plant such as the financial requirements, the human element of handling the workmen and the tremendous factors of that kind which did not exist 100 years ago. On the other hand, I think we can approach the efficiency of the old system if the engineers will grow to the point to which I am sure they can grow, and that they will attain in the not very distant future.

The engineer is expected today to know in general the foundation principles of the vehicle he is designing, the use to which it is to be put, the action of the various parts and the probable strains to be met therein, the general theory of combustion in internal-combustion engines and like matters. I do not see why the man who is mentally capable of understanding and applying those principles is not mentally capable of understanding and applying what to me are the much simpler principles of machine production. The fully equipped engineer should be thoroughly conversant with the principles of cutting metal of all kinds in all forms. These principles are really simple and actually very few in number. In addition, the well-grounded engineer should know the capacity for accuracy of the various production operations. For instance, he should know what a grinding machine that grinds shafts of 1-in. diameter should be able to do, day after day, in thousandths of an inch of tolerance either way from the desired size. He should know the same things regarding the grinding of cast-iron cylinders, the machining of aluminum parts and the cutting of gears. Not only should he know these things but, in preparing his designs, he should use such knowledge at the start.

Some engineers feel that the shop will take care of these things and that the whole burden on them is to have something that will run. That is the fault of specialization. Unless the engineer has the fullest comprehension of the difficulties to be met in the shop and gives as much attention to those questions as he does to the questions of the best form of combustion-chamber and the kind of spark-plugs to be used, we cannot get the efficient operation of our factories that we ought to have. The shop, under those conditions, has to meet the engineer half-way. I have had experience with seven factory managers in the last five years. The difference between the best and the worst of those factory managers was almost

entirely in their point of view. The best one took the viewpoint that he was building an operating engine. He encouraged his foremen and his superintendents to look at it in the same way. The reverse of this condition is when the foremen and the superintendents look at the product solely as so many piece numbers for which they have blueprints and what is to them an entirely arbitrary inspection. My contention is that the shop which educates its personnel to realize that the inspection is not arbitrary, that it is based on certain definite requirements, will go a long way toward obtaining the highest class of results in the cheapest possible manner.

Salability of the Product

I think another branch of the automotive industry comes equally within the province of the engineer; it is the salability of the product. It is much more conceivable to me that the trained engineer is the best judge of what car should be built to meet a given public demand than that the sales department should be the best judge. The engineer knows what can be done and, if he is broad-minded enough and sufficiently observant, he ought to have a very thorough knowledge of why the public demand certain things in cars. I think it is not difficult to obtain such information without actually being an employe in a salesroom or a sales manager. In fact, I think the salesroom frequently produces a rather artificial point of view; it is the point of view of that day. The engineer's job is not to say what is salable today, but what will be salable two years hence when he shall have been able to design the piece of apparatus and the factory shall have had time to build it. That is why I say that the engineer, if his training is proper and if his point of view is correct, ought in general to be a better judge than the sales department of the proper thing to build to meet a given demand.

I am asking a great deal of the engineer. In fact, in many ways he must have a greater fund of correct information at his disposal than any other member of a company. He must know his own part of the work, the results of research in the past and of the research going on from day to day. In connection with production he must know the actual methods in many allied industries; he must know the general methods of drop-forging, the general methods of producing stamped sheet-metal work, and foundry and pattern-making methods. The automobile chassis plus the body includes in its structure almost every form of manufacture that we have today, and the engineer must have a thorough grounding in almost every one of those lines if he is going to do his part of the work successfully. I have outlined already the necessity for his knowledge of shop practice. He must have also a knowledge of merchandising which will lead him to have a correct judgment on what the public will want in the future, and a correct judgment that the article can be produced at the price that the public will be willing to pay for it.

I admit that today we do not live up to my ideals of an engineer, but I believe that, if the engineer will grow along the lines I have indicated, he will demand a much larger place in the industry than he fills today, because he will merit it.

ADDRESS OF H. W. ALDEN

THERE has been no time when the position of the engineer in the trade and particularly in the automotive industry has been any more at the parting of the ways than it is today. We have gone through a wonderful period of engineering development and experimental work; we have experienced an amazing time of commercial development, when almost anything that would run on four wheels would sell; and now, for the next few years and perhaps perpetually, we are faced with the situation of the survival of the fittest.

Engineer's Place Depends on Himself

In trying to outline what will be the position of the engineer in our industry, one of the things that occurred to me is that his position will be just exactly what the engineer makes it. In my work I come into contact with probably 150 different engine manufacturing companies more or less intimately; also with a good many purveyors of material. In some cases there are peculiar conditions to which what I say does not apply because of very unusual circumstances, but I have found it largely true that the standing of the engineering department in any commercial organization is measured very largely by the ability of the engineering department itself. As a concrete instance, if a motor-car company has a wide-awake, live engineering organization, that organization plays a very large part in all the activities of the company. If it is made up of individuals who are not any too strong, then that department does not cut very much figure and takes its instructions from other departments. Just what position the engineer will maintain in the automotive field or in any other field will be measured entirely by his service. Just so far as the engineer serves all branches of his organization and the industry with which he is connected, will he play a part.

We have engineers who have come from two sources. One is the so-called technical graduate; the other is the engineer who has come up through the ranks. I do not presume to make any class distinction between the two. Both those who have had a preliminary technical training in some engineering college as well as those who have carved their own way out and availed themselves of that line of study and development which they have gotten by their own hard work, have gathered together certain information, certain lines of thought and lines of action which it seems to me places a responsibility on them which does not rest on the shoulders of any other department in modern organizations.

Mr. Crane has spoken very forcefully of the necessity that the engineer know all sides of his business. I cannot let the occasion go by without emphasizing that. It is just as much the engineer's job, in my opinion, to know how a piece can be produced, as it is to design that particular piece; in fact, I cannot conceive how he can design a piece of apparatus intelligently unless he does know all the steps of production in that device. He may get something that will work, but he will not get the last word in that device. It is just as much the engineer's business to know where and how that article will be sold, as it is how it will be designed or made; but it is a very striking fact, as one talks with engineers and sees what they are doing, to notice how few engineers really seem to know what will be done with the product after they get it off their shoulders. My sympathy very frequently goes out to the shop man who has to make what the engineer designs, and to the sales department that must sell what the engineer designs.

So far as the individual in an organization is concerned, his value to that organization depends very largely upon the measure of responsibility which he is willing to accept. That is equally true of the engineering and the other departments in any company. All of us

know men, perhaps men connected with our own organizations, who think that their little responsibility starts at a certain point and stops at some other certain point. If they are given a job that starts somewhat earlier and goes somewhat farther, they will shy at it. That kind of an engineer will never get very far and, unless that spirit is eliminated from that individual, he will fade away some day and will wonder why.

Another characteristic of engineers, which is disappointing in many instances, is lack of thoroughness. It frequently is necessary to gather some information from which to draw a conclusion; to build up some device, we will say, to take the place of the device that is being investigated. I venture to assert that there are not five men in a hundred who can go out and make an investigation of the situation and come back with the solution. The man who cannot come back with the solution is not particularly valuable.

Briefly, I believe that the position of the engineer in the automotive industry today is at the turning point, and that he can make it just exactly what he wants to make it. The engineer ought to be the central figure in our organization but, unless the engineering organization in any business serves all branches of the business and merges its own individuality, ignoring questions of who is responsible for this or who is to get the credit for that, we will not progress as we ought to progress. I doubt if there is an engineering society in the world that has such an opportunity to serve its industry as the Society of Automotive Engineers has; but only insofar as we are of service will we succeed in attaining our proper position in that industry and in maintaining it.

ADDRESS OF F. E. MOSKOVICS

THE individual that Mr. Crane described is not an engineer; he is an industrial wonder. When he attains such a position, he becomes the president of his firm. Mr. Crane left out only the financial side. Why he left out that detail I do not know. If the engineer is to be a judge of the commercial side of the demand without consultation with the sales department and can design the methods of production without consultation with the tool-designing and the production departments, why should he not know the small details of finance?

There are two forms of engineering that are not clearly recognized in their exact sense. I refer to those two forms constantly in our own business. There are some contacts that I believe no human being can get. A question just asked me proves this to my mind: "About what proportion of closed bodies are we going to build?" I said that limitations are put on one man, if nothing more than the limitations of geography; as long as San Francisco and Los Angeles persist in being 2000 to 3000 miles from our source of production, I do not see how an engineer can be out there every two or three months.

Two Forms of Engineering

The two forms of engineering that I believe are developing more and more as the keynote of our industry are the following. First, technical engineering, which can be taught in any first-class school. The man who studies the other form I would call an empirical engineer. I do not know but that the empirical is a somewhat more important form than the other. The empirical engineer is the very type that Mr. Crane described. I have found that the very finest machine in the world, founded on the very best technical information, can be designed and that one or several can be built, driven to San Francisco or any other place on a test trial, brought back and put into production; and then that when a thousand or more are put out there is something wrong. It is that something that I do not believe any one man can eliminate from an automobile without the cooperation of a number of other departments. The secret, to my mind, lies in those operations that can be turned into cooperations. That will bring us to the desired result. I think the czar that Mr. Crane described cannot do it without a most hearty cooperation of all the other branches, and unless he accomplishes it in the form of cooperations. If he is a czar, he might just as well have the name of it and be the president of the organization first as last. I will concede that interpreting the trend of future design is the greatest function of an engineer, but I believe that the engineer must temper his effort and be controlled by intelligent discussion and cooperation. A man cannot sit down and dictate some certain thing the public ought to have without having the ability to interpret that thing intelligently. To interpret it, he must have contact with the public. So long as the public persists in living in various places in different parts of the world, the man who interprets must listen to the salesman and the advertiser.

As to the cooperation of an engineering department with a production department, I cannot see it in any other way than that of actual contact between the two departments. I have for years past heard it said, not only in the last several years but in all the years that I have been connected with the automotive industry, "The design is absolutely right if only the production department would make it according to the drawings." The answer is that they would be right if only the production department could make the drawings commercial. If we can find an engineer that is a tool-maker, a designer, a shop superintendent and a sales executive, I will admit that he ought to be everything that Mr. Crane recommends, but then he could not be called an engineer.

ADDRESS OF J. G. UTZ

IN listening to the remarks of Mr. Moskovics and to the various statements that have been made about cooperation, I am reminded of a remark I heard made some time ago. It is that the difference between failure and success is the difference between dignified acquiescence and cheerful cooperation. I think that engineers are getting more toward the latter field as we go along. The greatest development of the American engineering profession, particularly in the automotive line, has been brought about largely by the Society of Automotive Engineers. Some of us who were in the old mechanical branch of the Association of Licensed Automobile Manufacturers remember, in fact, so many years ago that only a few gray-haired men here and there can remember, that there was a time when the experimental department, the engineering department and most parts of the shop were under lock and key and had guardians at their doors. Going back into the ancient history of that time, I can remember a meeting of the A. L. A. M. at 7 East 42nd Street. Something was asked about the fit of piston-rings. Almost everyone told what he was doing but, in going around the room, they finally called on one member who said he believed he would keep his information to himself and that he did not want others to build as good a car as he himself was building. That attitude was prominent in those days, but it has gradually dis-

appeared. Today, when traveling around as I have the good fortune to do now and then, about the first thing an engineer desires is to take a visitor down to his experimental room and show him what he is working on. The visitor sees things which will not become public for several years. The former practice of the profession was rather to keep such things to oneself. The very openness of the methods of engineers today, in regard to showing what they have, is one of the best criterions of the advancement of the American engineer. This practice is growing all the time.

I do not believe the statement that the Society of Automotive Engineers is standardizing the engineer out of a job is entirely true, although one can nearly design a car from the S.A.E. HANDBOOK today. Growth and advancement are evidenced by the fact that engineers are being moved up to positions of greater authority. We have some examples of engineers having arrived at the vice-presidencies and presidencies of their companies.

ADDRESS OF J. G. VINCENT

MR. CRANE and Mr. Alden have given a very good picture of why the engineer must in self-defense be thoroughly proficient. I think that one need go no further than just to realize that there is nothing in connection with the automotive industry that cannot be blamed on the engineer, thus proving that the engineer must be prepared to protect himself at every turn against every other department if he is to make a success. I know of no other department, in manufacturing or in the selling organization, that cannot be checked up with proof as to whether it is efficient. There is no really good way to check up whether an engineering department is efficient until all the processes have been gone over and the business made a success. Anything along the entire line can slip unless the engineer is there to protect himself.

ENGINEER SHOULD COOPERATE

Mr. Moskovics took a different viewpoint from what Mr. Crane and Mr. Alden had in mind. I know that neither of the latter had in mind that this engineer should be a czar or that he should be anything except the finest cooperator in the world. What they did have in mind, however, is that he must know his business, so that the result of this cooperation will be along the right line.

I have had some personal experience in that connection. In one plant where I took charge of the engineering there had not been the proper cooperation between the factory and the engineering department. The engineering department said that the factory did not want to work to drawings, was not interested in building the kind of a vehicle that ought to be built, and that it could not get the factory to work to drawings. On the other hand, the factory said that the engineering department did not know anything about designing and drawings. There you are! We cannot expect cooperation until both parties have a fair idea of the other's job. If the head of the engineering department and his assistants know shop practice and have the right mental attitude, they will not have much difficulty in getting full cooperation from the shop. Most shops, if they are managed properly, really appreciate cooperation.

So far as the sales department is concerned, the engineer will have no trouble there either. He cannot, of course, have full details of information as to all that is going on throughout the entire country. The members of most engineering departments whom I know of are too busy to take extended trips very often, but if the engineer is the right kind of a cooperator and has the proper initiative he will be so closely in touch with the sales department that he will know more about those conditions than they themselves will know. This is because he will know the engineering reasons that underlie the results that the sales department is obtaining, or the results it is not obtaining. I think there is no doubt that the engineer is taking more and more responsibility for the various activities throughout the various plants. As Mr. Moskovics says, he is working then toward becoming an executive. Well, why not? I know many big executives in this country who have worked up from having been engineers. I can think of nothing better than a good engineering training and experience to fit a man for executive work.

THE MOTOR CULTIVATOR

OVER 40 per cent of the total crop area of this country is devoted to the growing of crops planted in rows. These rowed crops represented over 50 per cent of the total crop value in 1919. Corn is the leading crop of the country, both in acreage and value. Hay and wheat are very close for second and third places and cotton is fourth. Thus two of our four leading crops require cultivation and are adapted to the use of the motor cultivator. These rowed crops, all big revenue producers, require more man labor and horsepower-hours per acre than most other crops, and it is therefore important to use the most economical methods possible in their production.

In the States of Iowa, Illinois, Nebraska, Missouri, Kansas, Indiana and Ohio, the percentage of rowed crops to total crop area varies from 46.6 in Iowa to 23.9 in Kansas. This is the region where power farming has had a great development, and in which the motor cultivator should be most rapidly introduced. In such States as Michigan and Wisconsin, where a general type of farming is followed, the percentage of the total crop area in rowed crops is not large. The introduction of the motor cultivator into these States will depend largely upon the extent to which it can be used for other work, and it is possible that in such States the preference may be given to the general-purpose type of machine.

One cannot study the figures showing the relative importance of rowed crops in American agriculture without becoming convinced that the motor cultivator has a great future. There can be no doubt about the possibilities for the general use of this machine. The next question is, what does it offer from the farmer's standpoint. In the first place, it means a saving of time in cultivating rowed crops. With a two-row machine one man can cultivate from 10 to 25 acres in 10 hr. depending upon the condition of the crop. When the plants are small the rate of travel is necessarily slow, but as they become larger the speed can be materially increased.

In addition to the cultivation of rowed crops this machine can be used to pull soil preparation machines, such as the disc and the harrow; drill grain, plant rowed crops, mow hay, cut grain, pull the hay-rake, tedder and loader and operate belt-driven machines that do not require more than 12 hp. This prime-mover is so new that its full possibilities for general work on the farm are not fully realized as yet.

The present situation regarding the motor cultivator can be summed up as follows: (*a*) there is a big potential market; (*b*) the machine is practical; (*c*) relatively few have been sold and (*d*) in many territories it has scarcely been introduced.—E. A. White in *Farm Implement News.*

THE BASIC INDUSTRY

NEARLY one-third of the people of the United States, or more than 30,000,000, live on farms. Nearly 20,000,000 more live in communities having a population of less than 2500. In other words, nearly one-half of the population of this country is to be found on farms or in the country districts. The farming interest is not comprised entirely, however, of those who actually live on the farms. Something like 40 per cent of our farms are rented and many of the owners live in cities and villages. This means that among the merchants, lawyers, doctors, real estate operators, bankers and insurance men of our cities and especially the cities and villages in agricultural sections, there are owners of farms or men whose business is directly dependent on or connected with farming.

The amount of capital invested in farming is constantly increasing. In 1910 the value of all farm property was approximately $41,000,000,000, or more than the capital of all the manufacturing establishments, railroads, mines and quarries in the United States. The value of farm property in 1919 was estimated at more than $51,000,000,000. From 1860 to 1890 this value increased steadily, but during the decade beginning with 1900 the increase in the value of farm property was greater than the entire accumulation of farm property in all the preceding years of our history.

With the increase in the value of farm property there has come a remarkable growth in the value of the farm output. In 1879 this output was valued at $1,500,000,000. No startling growth above this level took place during the next 18 years, but in the 10 years that followed 1897 the increase was nearly 100 per cent. In the next 8 years it increased only about 50 per cent, but under the impulse of the war the output from 1915 to 1917 increased again by 100 per cent, reaching a total gross value of about $16,000,000,000.

The national income from the farm began to rise about the time the population began to increase more rapidly than the area of improved land under cultivation. While the total volume of farm crops increased only 10 per cent from 1899 to 1909 the population increased more than twice as rapidly, so that with the increased demand for the crops the total value of the crop output increased by 83 per cent. This situation seems likely to continue in view of the steady drift of population toward the cities and towns. While 70 per cent of the population of this country lived on farms and in unincorporated villages in 1880, and 30 per cent lived in cities and incorporated villages in 1910 the city population was 55 per cent of the total. If from the 45 per cent representing the rural population there be subtracted the number of families living in unincorporated villages, it will be found that less than one-third of the population is now living on farms. Therefore, while in 1880 one farm family needed to raise enough food to sustain itself and part of another family, in 1910 one farm family needed to raise enough food to sustain itself and two other families.

Effect of the War

It has been stated that the gross farm income of the country increased more than 100 per cent after the war began. In the three oldest of the Middle Western States, Ohio, Indiana and Illinois, the average gross value of the 13 principal crops per farm in 1917 was $2,288, as compared with $964 on the average for the prewar period of 1911 to 1915, an increase of 137 per cent. It is estimated that farm costs increased 50 per cent during the war.

At this estimate the $964 received in the prewar period had merely covered the cost of production; one-half of this amount or $482 would represent the increase in the cost of production in 1917. Subtracting this from the total increase of $1,324 there is left an increased net profit of $842, an amount only $122 less than the average gross earnings on a prewar basis. Every section of the country showed a marked increase in the value of farm crops. The advance was least in New England, where the increase of 48 per cent was only about enough to cover the increase in cost. It was highest in the great agricultural belt of the central portion of the United States, showing an increase of 123 per cent in the Central West and South and an increase of 125 per cent in the area between the Mississippi River and the Rocky Mountains.

In 1904 the Department of Agriculture received appropriations of more than $6,000,000. In 1918 the appropriations were $68,000,000. In 1917 the amount appropriated for the support of agricultural colleges was nearly four times what it was in 1904. Agricultural colleges are the backbone of farming progress.

Use of Machinery

The use of motor-driven machinery and vehicles has enabled the farmer to save uncalculated amounts of time, energy and charges for maintenance. The telephone and the electrical plant have given the farmer advantages in production comparable with those derived by other industries.

As these mechanical contrivances have reduced in effect the size of the farm and saved labor they have made possible the extension of the area of cultivation. It takes about the same investment in buildings, the same self-binder, automobile and tractor for a farm of 100 acres as for a farm of 160 acres. The overhead charges are usually greater on a smaller farm. The tendency, therefore, is toward the larger farm. From 1900 to 1910 the number of farms in the classification of 20 to 100 acres tended to decrease and the farms from 100 to 175 acres in size remained about stationary, but farms of larger acreage, from 175 to 1000 acres, where the use of mechanical equipment is more general, showed a marked tendency to increase. There are about 1,150,000 farms of more than 175 acres in this country.

The trend of population toward the city has had a reflexive effect upon those who remain on the farms. They have not only sought to obtain for themselves the things which make living in the city attractive, but they have also assumed a different attitude toward the country. They have become less isolated. They have taken a keener interest in affairs. They have come into closer relations with their fellow men.

The County Agent

One of the most important forces in improving agriculture to-day is the county agent. There are 2920 agricultural counties in the United States. In over three-fourths of the counties a county agent is now employed. In several counties one or more assistant agents are also hired. They take out to the farmer better methods of farming, help him to produce more efficiently and to market his crops more advantageously to earn more money.

In addition to the county agents, some of the large city banks employ county agents who guide the farmers in applying loans to uses that will increase their net profits. In some instances railroads employ county agents. Banks, railroads and city chambers of commerce have actively promoted the county agent movement and have extended financial assistance.

In each of approximately 1700 counties a woman home-demonstration agent is employed to work with the farmers' wives and daughters. Not only are better methods of canning, care of poultry, etc., taught, but better sanitation and more home improvements are installed and more organizations of farm women are promoted. In the near future every agricultural county in the United States will probably have both a county agricultural agent and a home-demonstration agent.

Educational and Home Improvement

Education on the farm is improving. The one-room country school is slowly passing away. Its place is taken by the consolidated school, with a larger enrollment, better teachers

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Economy and Performance Demands

By J. G. Vincent[1]

Annual Meeting Paper

ECONOMY and performance are diametrically opposed to each other. In other words, the greater the performance demanded, the less the economy is likely to be. Peculiarly enough, when economy is mentioned, the average user thinks only about gasoline economy. On account of the fuel situation, it is very important that we work for greater gasoline economy; but if it were not for that, I think it would not be so important. As a matter of fact, the gasoline bill of the average user having an average car is not the major portion of his expense by any manner of means.

Regarding gasoline economy and supposing that we are considering gasoline economy on a type of car that has what is considered good performance, a car that will go nearly everywhere on high gear, such a car must have an acceleration from 5 to 30 m.p.h. in from 12 to 14 sec. The economy of that car is very largely determined by the engine design, the chassis design and the tires. I will point out the problems as I see them, because I do not know their solution. I wish I did.

Engine Design

The engine design is greatly limited in a certain way; that is, the economy is limited by the demand for performance. We can design an engine in any one of three ways. We can take a small engine, run it at high speed and use a big gear-reduction. We can go to the other extreme and design a large engine, run it at slow speed and use a small gear-reduction. We can design an average-sized engine, with an average gearing. The high-speed engine would probably be geared somewhat above 5 to 1, the average being about 5.25 to 1; the slow-speed engine might be geared about 2.50 to 1 or 3 to 1; and the medium-speed engine about 4 to 1 or somewhat lower. Granting that the engine is of good modern design and well built throughout, I believe there will not be much difference in economy between those three types of engine, provided the design is equally well carried out. I base that statement on the fact that the larger engine is likely to have to have slightly lower compression and to be somewhat less efficient; probably it will have less friction at the speed at which it normally runs.

I think we do not all realize that, whereas with a moderately light car having everything tuned up right we can drive say at 25 m.p.h. and get 20 miles per gal., if we could eliminate all the friction in the chassis and all the power that is required to turn the engine over, we could get 56 miles per gal. I am not in a position to prove this statement, but we have made some very exhaustive tests. I believe we have been attributing too much of the lack of economy in engines to throttle conditions, and that we have not been paying enough attention to the friction, particularly the friction of the engine which requires horsepower to turn it over. In other words, we are burning much more gasoline to turn the engine over than is required to drive an average car 25 m.p.h. This will bear investigation.

As to the chassis, there are many good types of design. It is not my task to discuss design, except to say that the chassis should be of well-balanced design in which friction is cut down to the lowest possible minimum, and that the adjustments should be so easy to make that the driver will not be compelled to drive the car with dragging brakes, or anything of that kind.

Tires

Considerable progress has been made in the quality of tires. I believe most of the best-known tires today, especially those of the cord type, give about uniformly good results. There is such a thing as over-tiring as well as under-tiring a car. Tires of adequate size only should be installed; I do not believe in what might be called the over-sizing of tires. I am assuming, of course, that the tire is properly selected in the first instance.

In the matter of oil economy, I think it is possible to obtain too much oil economy at the expense of something else. When we did not have the oil under control, we were constantly trying to reduce the oil consumption. I have been astonished to find out how little oil I could use but, after more experience, I learned that this reduced oil consumption was not all that I had thought it would be. With less lubrication, particularly with decreased cylinder lubrication, I found that I got into many other difficulties such as increased condensation in the crankcase, general wearing out of piston-rings and the like. So long as we use the present fuel we will have trouble with condensation in the crankcase and with the oil. Therefore, the oil should be changed occasionally. The best way to insure that the oil will be changed is to use a reasonable amount of it, although not enough to cause trouble.

Tire economy is an important item of saving. We will get the best tire economy if we build chassis with good brakes, smooth engines and gearboxes, so that we will get a smooth pick-up. An all-around smoothly operating car will give the best car economy per ton-mile. We cannot lay down rules as to how large or how small we will build cars, because different kinds of people demand different kinds of service.

Service Requirements

Another item that is apt to be overlooked in some cases is the matter of design from the viewpoint of service. The principal items, aside from the first cost of the car, are probably tire repair and depreciation. Tires, next gasoline and lastly oil are the main supply items. Service will cost in proportion to how simple, sensible and reliable the design is. We should pay more attention to simplicity. We think we have been paying attention to reliability and, after that, simplicity and accessibility. All cars have been offenders to some extent in lack of accessibility. It is good experience to operate some of the newly designed cars and to maintain them oneself for a few months before talking about turning them over to the factory; in that way one finds out what parts must be taken off to gain access to some other part that requires attention.

As to the matter of performance, I am inclined to agree that people do not like to shift gears, because they are

[1]M.S.A.E.—Vice-president in charge of engineering. Packard Motor Car Co., Detroit.

hard to shift. We must recognize the fact that greater gasoline economy requires more gearshifting. We have been making the gearshift harder because, as the parts speed up per mile traveled, the parts that must be handled in shifting gears increase in effective weight rapidly. Still, there has been much improvement along the line of gearshifting. Whether the gearbox should have consideration I am not prepared to say. Certainly it should if we make any great changes in the matter of performance. In other words, in the interest of economy we may approach nearer to the European type of car and if so we must improve the gearshift.

ENGINEERING AS A PROFESSION

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stantly in mind the necessity of production and studies the methods of production almost as carefully as the general functioning of the design and the production department conscientiously endeavors to carry out the ideas of the engineer as closely as possible in actual production that there can be any real approach to the efficiency of the old one-man system in which the design and production were controlled by the same directing head. It is equally necessary that for a design to be commercially successful it be attractive to the public, both in its operation and in the price at which it can be sold at a profit. This is where the opinion of the engineer ought to be of great value on questions that are often decided by the sales division. The engineer with a proper training and a correct point of view should be the best judge of what can be produced to meet most nearly the public demand in any particular field.

Leadership in the Conservation Movement

This very brief study of what engineering has done, what it frequently is and what it can be, has been introduced to make clear the tremendous opportunities that in my opinion will be open in the future to the men having a thoroughly sound engineering training. There is another phase of this question that deserves consideration. In the industrial history of this rapidly growing country there is every evidence that the great pressure of haste has caused the doing of many things in inefficient and uneconomical ways. Whether or not the wasteful methods of the past have been always justifiable, there can be no question that the time has come when everything possible must be done to conserve what remains of our originally tremendous natural resources. It is only necessary to mention timber, coal and petroleum to emphasize this point. The trained engineer is better qualified than anyone else to take the lead in this important work.

What has been said previously regarding the great future for the profession of engineering shows also the value of a proper engineering education. Such an education is not only of value to those expecting to engage in engineering occupations but also to those intending to take part in general productive or operating activities. The underlying idea in the best engineering schools is to teach the habit of concentration and to encourage clear and logical thinking, the actual knowledge gained during the years of study being considered a valuable incidental but not the main object of the work. It is hardly believable that this mental training will not prove to be a fine preparation for many of the difficult tasks that are daily to be met with in the industrial world of today, whether these tasks are of an engineering nature or more directly concerned with problems of direction or of management.

It is recorded of President Lincoln that after he had grown to manhood he made a most thorough study of Euclid because he believed that this would help him in formulating his ideas and in presenting them clearly to others. His conclusion was that the most complicated proposition could be put in such simple form as to be demonstrated to and understood by the least intelligent. What more convincing argument could there be as to the general value of this kind of training than that it was made use of by our great president in developing a truly remarkable ability for meeting the many difficult situations arising during his presidency and promptly reducing to the simplest terms the problems presented to him?

THE BASIC INDUSTRY

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and a more interesting school. In this school, agriculture, domestic science and manual training are taught.

A study of all the farm homes in Orange Township, Blackhawk County, Iowa, was made by the Iowa State College. Half of all the farm homes in this township had furnaces, while the proportion having water, baths and electric or gas lights was somewhat less. Nearly half of the homes had such labor-saving conveniences as vacuum cleaners, power washing machines and electric irons. Nearly all these homes had telephones, more than half had pianos and about half of them had automobiles. Each home improvement calls for others. For example, it is the general experience of distributors of electric lighting-plants that the purchase of a lighting-plant is followed by the purchase of a considerable amount of better furniture and house furnishings. Better wall paper is required. More paint and varnish are used. When the electric lights are turned on, the rugs, the furniture and the other house furnishings, which seemed satisfactory when kerosene lamps were in use, are not now so attractive.

The electric powerplant makes it far easier to have a water system in the farm house, with indoor toilet and bath, and to have the water system 100 per cent efficient. The power washing machine, the electrically operated ironing-machine, the vacuum cleaner, the electric iron and the electric fan can be utilized. The water can be pumped, the churn operated, the grindstone turned, the cream separated and a variety of other minor operations performed in and about the farm home by electric power.

The forces of necessity and desire are working together to increase the complexity of relationships between the farming element and the rest of the country, and interdependence beyond the mere traffic in food is generally recognized.—Guaranty Trust Co. of New York.

Publications of Interest *to* S. A. E. Members

In this column are given brief items regarding technical books and publications on automotive subjects. As a general rule, no attempt is made to give an exhaustive review of the books, the purpose of this section of THE JOURNAL being rather to indicate from time to time what literature relating to the automotive industry has been published with a short statement of the contents.

ANGLES OF ATTACK AND AIR SPEEDS DURING MANEUVERS. By Edward P. Warner and F. H. Norton. National Advisory Committee for Aeronautics Report No. 105. Published by National Advisory Committee for Aeronautics, Washington. 12 pages.

In seeking further information as to the nature of maneuvers and as to the maneuverability characteristics of airplanes, continuous measurements of the angles of attack and air speeds at several points along the wings were made during spins and loops. Very striking results were obtained with reference to the rolling velocity and the distribution of load in spins and the variation of the angle of attack in loops, a surprisingly large range of angle being experienced during slow loops.

PHYSICAL PROPERTIES OF MATERIALS. Bureau of Standards Circular No. 101. Published by Superintendent of Documents, Government Printing Office, Washington. 52 pages.

This circular aims to present in readily accessible form the best available data on the strength and related properties of materials. Among those treated are iron, carbon and alloy steels, wire and wire rope, semi-steel, aluminum, copper, miscellaneous metals and other alloys, rope, rubber, leather and wood. The tensile strength, proportional limit, percentage of elongation in 2 in., percentage reduction of area, Brinell and scleroscope hardness corresponding to a certain composition, density and method of preparation are shown in most cases for the metals and alloys. The S. A. E. Standard steels are covered fully in these tables. In addition, figures are given in many instances for the compressive and shearing strengths, moduli of rupture and Erichsen values. The circular also includes definitions of the properties treated and references to sources.

REPORT ON PERFORMANCE AND DESIGN OF FIVE REPRESENTATIVE GEARED AVIATION ENGINES. Air Service Information Circular, Vol. 11 No. 143. Published by the Chief of Air Service, Washington. 34 pages.

This report embodies complete descriptions of American-built geared engines with data on performance tests. The tests conducted were not sufficiently comprehensive to warrant definite conclusions as to the relative merits of the various types. The results indicate, however, that while several apparently successful forms of gearing are available, the engines themselves must be better adapted to the increased stresses due both to the presence of the gear train and to the high speed at which geared engines are usually operated. Data giving the mean effective pressure, fuel consumption, torque, horsepower, mechanical efficiency, etc., are tabulated for each test.

EDUCATION FOR HIGHWAY ENGINEERING AND HIGHWAY TRANSPORT. Department of the Interior, Bureau of Education, Bulletin No. 42, 1920. Published by Government Printing Office, Washington. 134 pages.

On May 14 and 15, 1919, a conference on education for highway engineering and highway transport was held at Washington which was attended by about 75 highway engineers, deans and supervisors of engineering in colleges, universities and technical schools, National, State and county highway commissioners, and men interested in highway and automotive transportation. The proceedings of the conference have been edited for publication as a bulletin of the Bureau of Education which contains much material of immediate and practical value to those who are directly interested in the problems of education for highway engineering and highway transport.

THE FACTORS THAT DETERMINE THE MINIMUM SPEED OF AN AIRPLANE. By F. H. Norton. National Advisory Committee for Aeronautics Technical Note No. 54. Published by the National Advisory Committee for Aeronautics, Washington. 9 pages.

A large range between the maximum and minimum speeds of an airplane is of undisputed value, either to permit safe landings in small fields with the medium or slow-speed machine, or to permit landing at all with very high-speed machines. The factors which limit the maximum speed are well understood, but rather strangely the limiting factors of the minimum speed have seldom been understood. The factors that affect the minimum speed are discussed with the hope that some of the present uncertainty will be cleared up.

THE FREEZING POINTS AND SPECIFIC GRAVITY OF ALCOHOL-WATER MIXTURES. Air Service Information Circular, Vol. 11 No. 178. Published by the Chief of Air Service, Washington. 6 pages.

Solutions of alcohol and water were prepared having a concentration at 2½-per cent intervals from 0 to 50-per cent concentration of alcohol by volume. These solutions submitted to low temperatures causing complete solidification or freezing of the mixtures, the melting point being determined upon slow warming. Tables show freezing point and specific gravity of denatured alcohol-water mixtures at 2½-per cent intervals from 0 to 50 per cent by volume of alcohol, these data also being reproduced in graphic form.

THE CALCULATED PERFORMANCE OF AIRPLANES EQUIPPED WITH SUPERCHARGING ENGINES. By E. C. Kemble. National Advisory Committee for Aeronautics Report No. 101. Published by the National Advisory Committee for Aeronautics, Washington. 52 pages.

In this report are presented the theoretical performance curves of an airplane engine equipped with a supercharging compressor and a graphical method is outlined whereby performance curves for either type of engine-compressor unit at all speeds and altitudes may be laid out with the aid of assumed compressor characteristics. Comparative performance curves for a Liberty engine operating with a turbine-driven compressor, a gear-driven compressor and without supercharging are derived in an illustrative calculation. A supercharging installation suitable for commercial use is described, and it is shown that with the aid of the compressor a great saving in fuel and a considerable increase in carrying capacity can be effected simultaneously.

RECENT EUROPEAN DEVELOPMENTS IN HELICOPTERS. National Advisory Committee for Aeronautics Technical Note No. 47. Published by National Advisory Committee for Aeronautics, Washington. 18 pages.

This report, which was prepared by the Paris Office of the National Advisory Committee for Aeronautics, describes two experimental types of helicopters developed during the war. One is designed to serve as a captive machine for artillery observation. A model of this type propelled by three rotary engines driving dual propellers actually ascended to a height of 50 meters. It possessed an excess lift equivalent to the weight of four men on the ground. A photograph is shown of this machine in flight.

APRIL COUNCIL MEETING

THE April Council meeting was held in Detroit on the 25th. The Council received a report from the Research Committee which held a meeting in Detroit on the same day.

ACTIVITIES OF THE SECTIONS

THE Annual Nominating Committee of the Society will meet during the Summer Meeting at West Baden and perhaps make its selection of candidates for officers of the Society for the year 1922. Each Section elects one member to serve on this Committee and it is desirable that the delegates so chosen have adequate knowledge of the wishes of the members of their Sections as to the men to be proposed for the various offices in the Society. Suggestions along these lines given to the delegates will be carefully considered by the Committee.

The number of reservations for the Summer Meeting received at the middle of April is shown below, geographically distributed as indicated.

Connecticut	7
Illinois	29
Indiana	39
Iowa	1
Massachusetts	6
Michigan	118
New Jersey	11
New York	75
Ohio	90
Pennsylvania	35
Virginia	1
Wisconsin	3
	415

A special train will run from the East over the Pennsylvania system to West Baden. The train schedule will be

Monday, May 23	
Leave New York (Pennsylvania Station)	9:10 a.m.
Leave North Philadelphia	11:16 a.m.
Leave Washington	10:10 a.m.
Leave Baltimore	11:15 a.m.
Leave Harrisburg	2:00 p.m.
Leave Altoona	5:00 p.m.
Leave Pittsburgh	8:25 p.m.
Tuesday, May 24	
Leave Columbus	12:35 a.m.
Arrive West Baden	11:00 a.m.

Special cars will also leave from Chicago, Cleveland, Detroit and Indianapolis. Members in these districts should communicate regarding train accommodations with the Secretaries of their respective Sections whose names and addresses are given below.

Cleveland Section—A. E. Jackman, Secretary
1900 Euclid Avenue, Cleveland

Detroit Section —M. H. Cox, Secretary
1361 Book Building, Detroit

Indiana Section —B. F. Kelly, Secretary
Weidely Motors Co., Indianapolis

Mid-West Section —L. S. Sheldrick, Secretary
910 South Michigan Avenue, Chicago

Round trip transportation at a fare and one-half has been arranged from all points east of Chicago and St. Louis, north of the Ohio River, and of Washington and Norfolk, except New England. Members from New England may secure the reduction from New York or Albany. These special rate tickets must be used within certain time limits and over the same route in both directions and are not good for stopover except between connecting trains. Reservations may be made on the S. A. E. special train or Section cars by those purchasing either one-way or round-trip tickets.

Recent Meetings

At one of the best attended meetings of the season, held at the Cosmos Club on April 1, Brigadier-General William Mitchell told the members of the Washington Section of the plans being made to test during the coming summer the effectiveness of aircraft attacks on battleships. In his description he stated that no defense from the ground or water would be efficient against an attack from the air and that only counter-attack from the air could be depended upon. Anti-aircraft fire was used during the war chiefly to protect balloons.

Six thousand feet was given as the best altitude for bombing from the air and present accuracy was stated to be about 10 times better than it was in the past war. Three-inch deck armor is the limit of thickness that can be pierced by gravity bombs but it is not known yet whether it is necessary to actually pierce this armor as the bombs may do sufficient damage otherwise. This is one of the questions it is planned to settle in the bombing tests this summer. England and France, General Mitchell said, are now carrying out similar tests. A striking comparison was made between the total weight of three types of missiles and the weight of the explosives they carry. Shells contain only 2½ per cent of explosives, and torpedoes 20 per cent, while aircraft bombs have over 50 per cent of their weight in explosives. The Air Service is planning to attack ships first with gas bombs, then with 300-lb. high-explosive bombs, following with 1100-lb. high-explosive bombs. The 1100-lb. bombs are expected to have a serious effect on a ship if they drop within 60 ft. of it. It is planned to make tests of this on one of the surrendered German battleships. The General described some recent American developments in airplanes and bombs, stating that the United States is making very rapid advances and that all-American equipment of excellent performance ability has been developed, making this country independent of foreign sources. In concluding he said in reply to a question that the battleship is not yet obsolete but that it might be superseded by aircraft within the next 20 or 30 years.

Major H. W. Harms, technical expert of the Air Service, gave a comprehensive account of the aircraft and equipment being developed by the Air Service, illustrating his talk with numerous lantern slides. The Air Service plans to develop four general types of airplane for 15 kinds of service, an effort being made to combine the various requirements in a small number of machines with the object of standardizing them.

Officers of the Washington Section for the coming Section administrative year were elected. Dr. H. C. Dickinson and Wm. S. James were named member and alternate to represent the Washington Section on the Annual Nominating Committee of the Society which will be organized at the Summer Meeting at West Baden.

Repair Equipment, by B. M. Ikert, and Welding, by Lorn Campbell, Jr., were the subjects presented before the Minneapolis Section at its meeting on April 6.

H. M. Beck gave a paper at the meeting of the Mid-West Section on April 11. His subject was Automatic Charging of Motive Power Batteries.

R. H. Beach and A. J. Weiss described a carburetion system which was developed for using kerosene and other fuels of low volatility in internal-combustion engines at the meeting of the Metropolitan Section held on April 14. The operation of the system is based on the heating of all of the mixture at low speeds in a coil which is enclosed in an exhaust chamber; at high speeds, the throttle is arranged so as to pass the charge directly into the cylinder. A lively discussion was had and some of the difficulties of utilizing kerosene as a fuel in passenger-car engines were brought out. It seemed to be the general opinion that the field for kerosene is limited to tractor, marine and stationary engines, where full-load conditions prevail most of the time.

That the sentiment of motor-car builders is turning more and more toward the possibility of lighter-weight construction is evidenced by the increasing number of discussions being held on this subject, one of which was led by Laurence Pomeroy at the Cleveland Section meeting on April 15, the subject being Aluminum in Engine Construction.

Another talk dealing with the subject of lighter weight was given by John D. Cutter before the Detroit Section on April 22. Mr. Cutter's paper was on Molybdenum Steel. When it is noted that about three-quarters of the weight of a car is

of steel, it will be recognized that the use of steel alloys has an important bearing on the total weight of the car.

The paper presented by A. E. White before the Detroit Section meeting on March 25 was received with unusual interest and, because of sentiment voiced at the meeting, it will be found elsewhere in this issue of THE JOURNAL.

F. C. Mock spoke on Carbureter Performance at the Buffalo Section meeting of April 19.

The Pennsylvania Section elected its officers for the coming year at its meeting on April 20.

Operating characteristics of Lead Acid Batteries was the subject of a paper read by H. W. Beedle at the Boston Section meeting on April 22.

During the past year the membership of the Society in California has increased from 116 to 154. This growth has been due largely to the efforts of the local Membership Committee. This committee has recently held a series of luncheons in San Francisco at the last of which on March 22 a group of over 30 members and guests listened to an informal talk by Past-President H. W. Alden of the Society. Col. Alden sketched the work and history of the Society, and referred to the possibility of forming a Pacific Coast Section. He spoke also of the recognition which automotive engineers must give to the problem of good roads and of the necessity of working with the highway engineers for the betterment of roads so necessary for the successful operation of the motor car and truck.

COMING MEETINGS

Section meetings scheduled for the month of May include one of the Indiana Section at Indianapolis on the 5th and a meeting of the Washington Section the following night. The Mid-West Section will hold a dinner and smoker on the 13th. It is expected that the final meeting of the Dayton Section for the present season will be held on the 17th and that of the Cleveland Section on the 20th.

THE TRACTOR ON CORN-BELT FARMS

WHILE the saving of man labor is frequently mentioned as an important advantage of the tractor, this factor does not seem to be of great importance in the corn-belt section. Some man labor is saved when a tractor is used in pulling a three-bottom plow instead of the two-bottom plow commonly used with horses. Some saving in man labor is effected also when discing and harrowing are combined as one operation. The combining of other operations such as harrowing and rolling may make possible some saving in man labor. However, the total saving in man labor effected by the tractor in performing the various operations of soil preparation does not appear to be more than a few days, from 10 to 15 perhaps on the average-sized farm using a tractor. This saving is not of very great importance because it is made during a period when horsepower rather than man labor is the limiting factor in getting the work done. The peak-load requirement for man labor does not come at the time of spring planting. It comes later on in June and July, at the time of corn cultivation, wheat harvesting and haymaking. At this season the tractor can effect little if any saving in man labor.

The data available from the Illinois tractor farms studied up to the present time indicate that as an average the tractor has displaced slightly more than 20 per cent of the horses carried before adding the tractor. Under the most favorable conditions and with the best management the maximum displacement has been almost exactly 33 per cent.

As an average of the first 100 tractor farms studied in six central Illinois counties it was found that the average size was 294 acres and that these farms grew slightly more than 240 acres of crop. On the average these farms used slightly less than 12 horses per farm, that is, they worked a little more than 20 acres of crop per horse. The tractor used displaced slightly less than 2½ horses per farm.

As a result of the studies made so far, based on the experience gained by Illinois farmers in 1918, 1919 and 1920, it appears that farms with less than 200 to 240 acres of crop have not been justified in using a tractor. Under special conditions where the demand for belt work is unusual or the tractor possesses special advantages because of the conditions obtaining on a particular farm, a tractor may prove to be a profitable investment even though the farm be considerably below the size which is apparently best adapted to using a tractor.

It is, of course, plain that these general conclusions must be regarded as somewhat preliminary, and that they will, of necessity, be revised as additional experience is accumulated, and as investigations in this field are extended and the methods of study improved.—W. F. Handschin in *Orange Judd Farmer*.

NATIONAL SCREW THREAD STANDARDS

THE progress report of the National Screw Thread Commission, as approved June 19, 1920, has been published by the Government Printing Office as miscellaneous publication No. 42 of the Bureau of Standards. Copies may be obtained upon application to Superintendent of Documents, Government Printing Office, Washington. An extensive abstract of the report was published in the October, 1920, issue of THE JOURNAL, page 317, this being based on a tentative report issued prior to that time in mimeographed form. Recognizing the impossibility of making a report of this character which in its first edition is entirely free from error or inconsistency, the Congress has extended the life of the National Screw Thread Commission for a period of 2 years, during which time such corrections and changes will be made in the report as are found necessary or desirable by practical trial of the recommendations of the Commission in the designing room and the shop.

The National Fine-Thread Series which conforms to the S. A. E. Standard regular thread is recommended for general use in automotive and aircraft work when the design requires both strength and reduction in weight and special conditions require a fine thread.

The general adoption of the S. A. E. Standard pitches in other than automotive lines of work is indicated by the practice of a well-known automotive company.

In this plant where pitches finer than U. S. Standard have in the past been used they are replaced at the first opportunity with S. A. E. Standard pitches. In new designs, where holes are tapped in steel, the S. A. E. Standard pitches are used.

Instead of tapping cast iron for binder bolts, through-holes are drilled wherever possible and S. A. E. Standard bolts used. The past practice of tapping holes in cast iron, brass and other soft metals, for U. S. Standard pitches, is continued except in a few instances where S. A. E. Standard pitches are being tried because the workmanship is more refined.

In the few instances where S. A. E. Standard pitches have been used, both in cast iron and in bronze, no trouble has so far resulted. The successful application of S. A. E. Standard pitches in such cases, however, is contingent largely on careful workmanship in tapping the hole and in the use of screws having threads that are smooth, full and accurately concentric. The use of S. A. E. Standard regular and fine pitches is being extended, insofar as they are adapted to the purpose, to the threading of component parts other than screws and bolts.

CURRENT STANDARDIZATION WORK

THE current standardization work of the Society has, in consequence of the general industrial situation, been carried on recently more extensively than usual by correspondence. Many Divisions are therefore holding but one meeting before the Semi-Annual Meeting of the Society on May 24.

The complete reports of the Divisions making recommendations will however be published in pamphlet form and sent to the voting members of the Society for consideration prior to the Standards Committee Meeting.

Chain Division

A meeting of the Chain Division was held on Nov. 17, 1920, in New York with the Roller Chain Committee of the American Society of Mechanical Engineers and the Committee on Sprockets of the American Gear Manufacturers Association. The session was given over largely to discussion of a standard tooth-form, the following recommendation being submitted for consideration:

> The pressure angle for a six-tooth wheel shall run from about 15 to 5 deg. The pressure angle on a wheel of infinite diameter shall run from about 15 to 30 deg., making the actual working face of the tooth a surface concave to the roller, the radius of which is approximately 1.3 times the diameter of the roller

This recommendation was adopted with the understanding that the Subcommittee on Tooth-Form would present a detailed report at a later date which would be considered approved unless some objection was raised by the Division members. The complete report is now before the members of the Division for letter ballot.

The Division recommended also the adoption of a numbering system for roller chains in which the left-hand figures denote the number of one-eighth inches in the pitch and the final figure denotes the roller diameter, "0" indicating that the roller diameter is for the heavy series, "1" indicating that it is the same as for chains of the medium series, and "2" indicating that it is the same as for chains of the light series, the numbers being followed by the letter "W" or "N" denoting whether the chain is of the wide or narrow series. Thus in a chain number 40W, the 4 shows that the pitch is ½ in.; 0 that it belongs to the heavy series and has a 5/16-in. roller diameter; and the letter W that it belongs to the wide series and that its width is 5/16 in.

Further work on the subjects of rollerless bushing chains and average breaking strengths is planned.

Engine Division

A meeting of the Engine Division was held on April 18 at Cleveland in the Old Colony Club rooms, the subjects of mufflers, carbureter flanges, engine testing-forms and fan belts and hubs being discussed.

Isolated Electric Lighting Plant Division

The Isolated Electric Lighting Plant Division members met at Chicago on April 11. Ratings of storage batteries for isolated electric lighting plants was the principal subject discussed.

Lighting Division

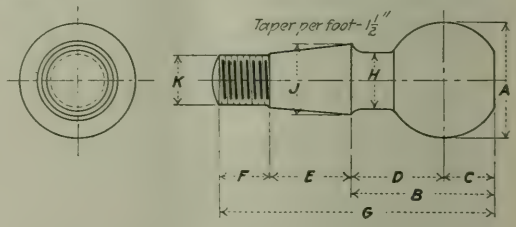
A lighting Division meeting was held on April 15 at Detroit to consider Subdivision reports on universal fender-type head-lamp mountings, lamp nomenclature and bases, sockets and connectors.

The proposed type of head-lamp bracket for mounting on fender aprons has been tried out satisfactorily in actual practice. The bracket will permit of universal adjustment of the lamp and interchangeability of lamps. The recommendation presented at the meeting was

> The bracket shall have a spherical mounting surface providing universal adjustment of the head-lamp
>
> The radius of curvature of the spherical mounting surface shall be 2½ in.
>
> The axis of the bolt holding the head-lamp to the bracket shall coincide with the axis of the mounting surface. The bolt shall be ½ in. in diameter, 1½ in. long and threaded with ½-in.—20 S.A.E. thread for a distance of ⅞ in. from the end
>
> The angle formed by the axis of the spherical mounting surface and the axis of the head-lamp shall be 55 deg.
>
> A plane passed through the center of the spherical mounting surface perpendicular to the axis of the head-lamp shall show the center of the mounting surface to be 60 deg. from the vertical
>
> The axis of the spherical mounting surface shall be perpendicular to the axis of head-lamps cylindrical in shape and 60 deg. from the vertical.
>
> The spherical mounting surface shall be attached to the outside of the lamp body
>
> No tie-rod lugs shall be made integrally with the lamp body
>
> The bolt-holes in the fender mounting surface shall be 13/32 in. in diameter and the center-to-center distance shall be 3 in.
>
> The fender mounting surface shall be parallel to the axis of the lamp
>
> It is understood that the mounting surface of the bracket is the male part and the mounting surface of the head-lamp the female part.

Parts and Fittings Division

A meeting of the Parts and Fittings Division was held April 19 in New York City. One of the principal subjects discussed was a report on ball studs ranging in size from 1 to 1¾ in. ball diameters which was presented by W. R. Strickland. Preliminary investigation showed that the variation of present practice made this fitting unnecessarily costly to the manufacturers and it was therefore requested that a standard should be formulated. The report which is in the form of a proposed standard is given in the accompanying table.



No.	A	B	C	D	E	F	G	H	J	K
1	1	1⅜	7/16	15/16	13/16	5/8	2 13/16	5/8	0.766	5/8-18
2	1⅛	1½	½	1	13/16	5/8	2 13/16	5/8	0.766	5/8-18
3	1¼	1 11/16	9/16	1⅛	1	¾	3 7/16	¾	0.875	5/8-18
4	1½	1⅞	5/8	1¼	1⅛	¾	3¾	13/16	1.000	¾-16
5	1¾	2⅛	¾	1⅜	1¼	1	4⅜	15/16	1.250	⅞-14

A Subdivision consisting of A. K. Brumbaugh, chairman, J. T. Spicer, H. G. Farwell, E. O. Christiansen, F. C. Stanley and Clarence Carson has been appointed to consider the subject of brake-lining dimensions and tests based on the work of the Truck Division Subdivision on Brake-Lining Specifi-

cations and Coefficient of Friction. This Subdivision did considerable work during 1920. A meeting of the Subdivision was held on April 1 in New York at which the subject of brake-lining tests was very thoroughly discussed, the work at the Bureau of Standards being described in detail. It was decided at this meeting that the members of the Brake-Lining Subdivision should construct testing apparatus similar to that constructed at the Bureau of Standards and make a series of tests with a view to deciding upon a definite specification for testing brake-linings. The importance of such tests was emphasized as the tests employed at the present time by the different automobile builders vary greatly.

Other subjects considered at the meeting were exhaust-pipe diameters, warning-signal mountings, serrated-shaft fittings, universal-joint companion flanges and lock washers.

Passenger Car Body Division

The Passenger Car Body Division meeting held on March 11 resulted in the assignment to Subdivisions of many subjects germane to passenger-car bodies which are considered by the Division members to warrant the immediate consideration of the Division. Among the subjects assigned are:

Top Irons	Wood-Screw Drill Sizes
Fender Irons	Door Fit Clearances
Plate Glass	Sheet Metal
Window Runways	Beads for Wiring
Door Handles	Nickel Plating
Door Hinges	Tee Moldings

It was the consensus of opinion that it is quite possible that there are other subjects more important than the ones listed above which should be considered by the Division for the purpose of formulating standards which, through general adoption by the industry, would decrease the manufacturing cost of the parts standardized, increase the sources from which they can be obtained and tend to decrease the cost of the finished products. The Division members will therefore appreciate further suggestions in this connection.

Electric Equipment Division

W. S. Haggott, chairman of the Subdivision on Insulated Cable, submitted a report at the meeting of the Electrical Equipment Division held on April 19 in Cleveland. This report was formulated after a series of Subdivision meetings attended by cable and electrical equipment manufacturers. The tests outlined in the report were based on the results of tests which have been carried on by members of the Subdivision. The complete report will be published in the pamphlet containing the reports of the Divisions of the Standards Committee, which will be sent to the members before the Standards Committee meeting on May 24.

Other subjects considered at the meeting were ignition distributor mountings, flexible-disc couplings and magneto, generator and starting-motor mountings.

Stationary Engine Division

A meeting of Stationary Engine Division members was held on April 13 at Waterloo, Iowa. Returns from general letters which had been sent out by the Society on the Division's recommendation on Stationary Engine Belt Speeds and Spark-Plug Hoods and Pulley Lug dimensions, which had been suggested for standardization, were considered. Several Subdivisions also presented progress reports.

VALVE-STEEL SPECIFICATIONS

AT the Standards Committee Meeting held last January certain S. A. E. Steels were unjustly criticized to the effect that nickel and nickel-chromium steels which were recommended for use in engine valves scaled excessively at high temperatures. It is generally understood that the Iron and Steel Division has not recommended specific compositions for valve purposes for many years and never recommended any of the nickel-chromium steels. Confusion has, however, been caused by the fact that in the notes and instructions typical applications have been listed indicating the use made of certain compositions covered by the S. A. E. Steel Specifications. These notes are published as general information only, not as an S. A. E. Standard or Recommended Practice. It is clearly stated, and is in general understood throughout the industry, that the notes and instructions are added solely for information of the users of the steel and do not constitute a part of the iron and steel specifications.

The main reason for not making specific recommendations a part of the S. A. E. Standards is that very frequently a wide range of material is used successfully for the same automotive part, and the selection of a specific material for a given use depends upon the design, production methods and many other factors that must be given careful consideration by the metallurgist or engineer in direct charge rather than by a metallurgical body working at a distance. The notes covering the tungsten steel specifications state that Specifications Nos. 71360 and 71660 are suitable for high-tungsten steel exhaust valves and that Specification No. 7260 is suitable for low-tungsten steel inlet and exhaust valves. "General Information" on high-chromium steel containing from 11 to 14 per cent of chromium is also published in the S. A. E. HANDBOOK and states that one of its principal uses is for exhaust valves in airplane engines. No other mention of valve steels is made.

A survey of what steels were used in actual practice for inlet and exhaust valves was made by the Society in 1920. A tabulation of the results is given in the accompanying table, the figures indicating the percentage of engine builders and valve manufacturers using each material for inlet or outlet valves. These data were based on returns received from 38 representative engine builders and valve manufacturers.

RELATIVE USE OF ALLOY STEELS FOR VALVES IN PERCENTAGE

Material	Inlet Valves	Exhaust Valves
Cast Iron	31	26
Nickel Steel	18	14
Chromium-Vanadium Steel	6	3
Nickel-Chromium Steel	19	18
High-Tungsten Steel	6	10
Low-Tungsten Steel	11	12
Carbon Steel	2	3
High-Chromium Steel	7	14

THE EDUCATIONAL SYSTEM OF THE ARMY

WITH a view to meeting the numerous requests for information concerning the educational and vocational training program of the Army and to set forth in a convenient form the plans and desires of the War Department for the improvement and recreation of the young men enlisting, a pamphlet has been prepared for distribution. Those who are interested in this important work can secure copies by addressing the Adjutant General's Office at Washington and asking for the pamphlet entitled The Educational System of the United States Army.

Applicants *for* Membership

The applications for membership received between March 26 and April 19, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ALEXANDER, C. K., sales engineer, Wheeler-Schebler Carburetor Co., *Indianapolis.*

ALVORD, C. H., factory manager, Gray & Davis, Inc., *Cambridge, Mass.*

ANDREW, DAVID, JR., secretary and sales manager, Arco Co., *Cleveland.*

BLUM, LOUIS E., JR., machine designer, Splitdorf Electrical Co., *Newark, N. J.*

BOYD, FRANK MORRISON, general manager, secretary and treasurer, Motor Parts Corporation, *Baltimore, Md.*

BRADY, L. J., assistant manager, Nash Sales Co., *Chicago.*

BRICE, JAMES W., International Finn Recorder Co., *Endicott, N. Y.*

BROCKETT, ASHLEY H., instructor, Carnegie Institute of Technology, *Pittsburgh.*

BROWN, GORDON, research engineer, Condensite Co. of America, *Bloomfield, N. J.*

BULLOCK, HOWARD F., district representative, United Motors Service, Inc., *Detroit.*

BURTON, EWART E., mechanical draftsman, Holt Mfg. Co., *Stockton, Cal.*

BUTTNER, EDGAR LOUIS, student, University of California, *Berkeley, Cal.*

CAMINEZ, HAROLD, aeronautical designer, Air Service, McCook Field, *Dayton, Ohio.*

CAREY, LIEUT. EDWIN F., office of Chief of Air Service, *Washington.*

CARVELLI, GUSTAF, designing engineer, Curtis Engineering & Motors Corporation, *Garden City, N. Y.*

CIAFFONE, JAMES V., designer and inventor, 427 12th Avenue, *Long Island City, N. Y.*

CONANT, DAVID J., chief engineer, Western Well Works, Inc., *San Jose, Calif.*

DALE, HARRY W., mechanical and research engineer, 2626 Broadway, *New York City.*

DANFORTH, I. W., sales manager, Gabriel Mfg. Co., *Cleveland.*

DAVIES, W. S., auto engineer, Wolseley Motors Ltd., *Birmingham, England.*

DEBRAY, WILLARD S., machinist apprentice, Pennsylvania Railroad Co., *Altoona, Pa.*

DEMARINGH, ALBERT F., sales engineer, Marburg Bros., Inc., *New York City.*

DE WITT, L. W., sales agent, National Malleable Castings Co., *Cleveland.*

DISBROW, LIVINGSTON, experimental mechanic, Pittsburgh Model Engine Co., *Pittsburgh.*

ENOCHS, C. D., vice-president and general manager, Shaw-Enochs Tractor Co., *Minneapolis.*

EVELYN, STEVEN F., designing engineer, Continental Motor Corporation, *Detroit.*

FISHER, ROY R., president and general manager, Ray Battery Co., *Ypsilanti, Mich.*

GAFFNEY, MICHAEL W., body engineer, Haynes Automobile Co., *Kokomo, Ind.*

GALLAGHER, FRANK J., technical assistant to fire marshal, *Philadelphia.*

GANDELOT, HOWARD K., service manager, B. W. Lemmon Co., *Pittsburgh.*

GATES, L. S., head of Gates & Co., *New York City.*

GESSLER, CARL W., consulting engineer, 5 Columbus Circle, *New York City.*

GIRDLER, LOUIS T., secretary and treasurer, Standard Automotive Parts Co., *Muskegon, Mich.*

GOEHDE, H. L., chief engineer, Colonial Motors Corporation, *Dorchester, Mass.*

HERMAN, FRED WOLD, student, University of California, *Berkeley, Cal.*

JAMISON, ALEXANDER C., sales representative, Sheldon Axle & Spring Co., *Wilkes-Barre, Pa.*

JOHNSON, CARL A., sales engineer, Hyatt Roller Bearing Co., *Chicago.*

JOHNSON, CARL W., factory manager and sales engineer, Cleveland Graphite Bronze Co., *Cleveland.*

JOHNSON, FLOYD CHARLES, experimental laboratory, Lincoln Motor Co., *Detroit.*

JONES, FRANK A., superintendent of automotive equipment, Roxana Petroleum Corporation, *St. Louis.*

JUDGE, ARTHUR WILLIAM, experimental engineer, Instrument Design Establishment, *Kent, England.*

LA FEHR, F. EDWARD, president, Detroit Carburetor Corporation, *Detroit.*

LANE, RALPH F., factory layout draftsman, Oakland Motor Car Co., *Pontiac, Mich.*

LAVIER, T. H., JR., chief engineer, Ray Battery Co., *Ypsilanti, Mich.*

LEAVITT, DUDLEY W., purchasing agent, Commodore Motors Co., *New York City.*

LEE, STEPHEN M., laboratory assistant, aeronautic powerplant, Bureau of Standards, *Washington.*

LIPPERT, RUDOLPH E., sales engineer, Drying Systems, Inc., *Chicago.*

MCCAULEY, J. E., chief engineer, Hayes Wheel Co. of Canada, *Chatham, Ont., Canada.*

MCFARLAND, W. LEWIS, service engineer, Motors Repair Co., *Nashville, Tenn.*

MCMILLAN, NIEL, JR., manager radiator division, National Can Co., *Detroit.*

MCMULLEN, V. E., general superintendent, gas engine division, Hercules Corporation, *Evansville, Ind.*

MARTIN, P. B., manager service stores, Westcott Motor Car Co., *Springfield, Ohio.*

MICHAEL, H. B., assistant engineer, Underwriters' Laboratories, *Chicago.*

MIESSE, JULES, proprietor, Usine Jules Miesse, *Brussels, Belgium.*

MUELLER, MAX M., superintendent, steering gear department, Borg & Beck Co., *Chicago.*

NIKONOW, J. P., consulting engineer, Room 413, 136 Liberty Street, *New York City.*

NILES, ALFRED S., JR., aeronautical structural engineer, Air Service, McCook Field, *Dayton, Ohio.*

NORDSTRUM, GEORGE W., secretary and treasurer, Aetna Ball Bearing Mfg. Co., *Chicago.*

OLIVER, LEONARD FENWICK, manager, Alcock, Ashdown & Co., Ltd., *Bombay, India.*

PEABODY, HUGH K., chief engineer, Gilbert Motors Co., *Boston.*

PETIT, H. A. C. P., engineer, *La Vie Automobile, Paris, France.*

PIERCE, EDWARD M., acting factory manager, engineering division, Air Service, *Dayton, Ohio.*

PRICHARD, LEONARD W., student, Tri-State College of Engineering, *Angola, Ind.*

ROWAN, A. H., factory manager, Southern Motor Mfg. Association, Ltd., *Houston, Tex.*

RUPP, JOHN L., manager of manufacturers sales, Westinghouse Union Battery Co., *Swissvale, Pa.*

SCARR, FRANCIS J., assistant to superintendent of motor equipment, Standard Oil Co., *Newark, N. J.*

SCHLUND, WILLIAM J., service manager, Peerless Motor Car Co., *Cleveland.*

SELMAN, EDWARD C., member of president's staff, Pierce-Arrow Motor Car Co., *Buffalo.*

STARNES, R. R., president and treasurer, Gearless Motor Corporation, *Pittsburgh.*

STEWART, ELLIOTT W., spring engineer, William D. Gibson Co., *Chicago.*

STONE, RAYMOND D., repair shop foreman, Birch Street Garage Co., *Roslindale, Mass.*

STROHM, GROVER E., sales engineer, Prest-O-Lite Co., Inc., *New York City.*

STURGES, HARRY A., mechanical engineer, Northway Motors Corporation, *Natick, Mass.*

SWEENEY, D. M., supervisor of distributor, United Motor Service, Inc., *Detroit.*

TUCKER, JOHN J., aeronautical mechanical engineer, engineering division, Air Service, *Dayton, Ohio.*

VALTIER, FRANK, industrial engineer, Milburn Wagon Co., *Toledo.*

WEBSTER, HARRY F., factory manager, Denman-Myers Cord Tire Co., *Warren, Ohio.*

WEINSTEIN, HARRY, student in industrial electrical engineering, Pratt Institute, *Brooklyn, N. Y.*

WERNER, RALPH M., chief engineer, Ralph M. Werner & Co., *Brooklyn, N. Y.*

WEST, PHILIP EARL, technical department division head, General Motors Export Co., *New York City.*

WESTON, EDWARD F., Weston Electrical Instrument Co., *Newark, N. J.*

WHEELER, EDWIN S., assistant manager technical department, International Nickel Co., *New York City.*

WILKINS, F. P., sales department, Waukesha Motor Co., *Waukesha, Wis.*

WILKINS, HAROLD S., engineer, H. C. Dodge, Inc., *Boston.*

WILLETT, E. F., manufacturers agent, National Gauge & Equipment Co., *La Crosse, Wis.*, and Bishop Gutta Percha Co., *New York City.*

WILLIAMS, G. M., general manager, Dayton Wright Co., *Dayton, Ohio.*

WILLIAMSON, JOSEPH F., lubrication and dynamometer engineer, Standard Oil Co. of Cal., *Richmond, Cal.*

WRIGHT, J. C., chief, industrial education service, Federal Board for Vocational Education, *Washington.*

WYLIE, ARTHUR R., patent attorney, Dyrenforth, Lee, Chritton & Wiles, *Chicago.*

ZIRKEL, P. J., chief tool designer, International Harvester Co., *Akron, Ohio.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between March 10 and April 9, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ABRAMOVICS, HARRY (J) draftsman and designer, Noma Motor Corporation, *New York City,* (mail) 516 East 88th Street.

BECHTLOFFT, CLAUDE B. (J) experimental engineer, Bijur Motor Appliance Co., Hoboken, N. J., (mail) *Ridgewood, N. J.*

BENNINGHOFF, WILLIAM E. (J) time study engineering, Western Automatic Machine Screw Co., *Elyria, Ohio.*

BLAKE, E. A. (J) in charge of experimental department, Transport Truck Co., *Mount Pleasant, Mich.*

BOUCHER, J. D. (A) manager of manufacturers' sales, Houdaille Co., *Buffalo,* (mail) Hotel Touraine.

BOVELL, SAMUEL C. (A) superintendent of equipment, Magnolia Petroleum Co., *Dallas, Tex.,* (mail) 5010 Reiger Avenue.

BRENNAN, C. H. (A) sales manager, Jefferson Forge Products Co., *Detroit,* (mail) 4137 Avery Street.

BROWN, LOWELL H. (A) president, Belflex Corporation, 366 Madison Avenue, *New York City.*

BURGELEIT, W. H. (M) designer, Durant Motors, Inc., Long Island City, N. Y., (mail) Room 807, 512 Fifth Avenue, *New York City.*

CARNEGIE, WILLIAM (J) draftsman, Cadillac Motor Car Co., *Detroit* (mail) 643 Hendrie Avenue.

CHAMBERS, ALEXANDER K. (A) district service manager, American Bosch Magneto Corporation, Springfield, Mass., (mail) 3737 Michigan Avenue, *Chicago.*

CLIFF, HARRY G. (A) cashier, Routt County Bank, *Oak Creek, Col.*

COLSTAD, CHARLES N. (M) mechanical engineer, 16 Tyler Street, *Norfolk Downs, Mass.*

COMFIELD, EINAR A. (J) chief draftsman, Available Truck Co., 1539 North Kilpatrick Avenue, *Chicago.*

CORE, EUGENE D. (J) president and general manager, MacCore Motors Corporation, corner Church and Ransom Streets, *Kalamazoo, Mich.*

CORFF, EDWARD VINCENT (M) mechanical and industrial engineer. 1845 South Spaulding Avenue, *Chicago.*

CORY, RUSSELL WILSON (J) layout and design draftsman, Cleveland Ordnance Engineering Office, Cleveland, (mail) 643 Darmouth Avenue, Southwest, *Canton, Ohio.*

DAHL, BARNEY (E S) 208 10th Street, *South Virginia, Minn.*

DAVIS, HOWARD LA MONTE (A) sales engineer, Connecticut Telephone & Electric Co., Meridan, Conn., (mail) 1734 Ridge Avenue, *Evanston, Ill.*

DELANY, HOWARD S. (A) member of firm, Delany & Co., Milnor and Cottman Streets, *Tacony, Philadelphia.*

DRYDEN, J. L. (A) general manager and treasurer, Long Mfg. Co., *Detroit,* (mail) 79 Delaware Avenue.

DUGGAN, THOMAS OSBORN (A) Pacific coast representative, Chanslor & Lyon Co., 1238 Van Ness Avenue, *San Francisco.*

EARL, HERMON (M) chief engineer, John W. Henney & Co., *Freeport, Ill.* (mail) Box 382.

EINSTEIN, ARTHUR W. (A) special engineering sales representative, Ward La France Truck Co., *Elmira, N. Y.*

ELMENDORF, ARMIN (M) consulting engineer, Haskelite Mfg. Corporation, 819 Chamber of Commerce Building, *Chicago.*

FAHNESTOCK, MURRAY (A) technical editor, Trade Press Publishing Co., Milwaukee, (mail) 9 Marshall Avenue, Observatory Station, *Pittsburgh.*

FENNER, PAUL R. (A) manager, R-S Mfg. Co., Kansas City, Mo., (mail) Box 931, *Dayton, Ohio.*

FESLER, J. A. (A) president, Alemite Lubricator Co. of Michigan, Detroit; special representative, Bassick Mfg. Co., Chicago, (mail) care Alemite Lubricator Co. of Michigan, 4750 Woodward Avenue, *Detroit.*

GAGE, V. R. (M) assistant professor of experimental engineering, Cornell University, Sibley College, *Ithaca, N. Y.* (mail) 119 Ferris Place.

GEIGER, JOHN W. (J) research assistant, Purdue University, Engineering Experiment Station, Mechanics Building, *West Lafayette, Ind.*

GIBSON, RICHARD, JR. (M) technical superintendent in charge of factory, Lancaster Tire & Rubber Co., *Lancaster, Ohio.*

GOCHNAUER, G. C. (M) chief engineer, Belmont Motors Corporation, *Harrisburg, Pa.,* (mail) Box 13.

GOSS, RAY B. (A) instructor, tractor, gasoline engine specialist, department of farm mechanics, Purdue University, *West Lafayette, Ind.,* (mail) 216 Sheetz Street.

HACKETT, FIRST-LIEUT. FRANK D. (A) Air Service, Mather Field, *Sacramento, Cal.*

HARVEY, JAMES D. (M) engineer, sales department, Stewart-Warner Speedometer Corporation, *Chicago,* (mail) 3024 Waterloo Court.

HECHT, ALEXANDER S. (A) proprietor, Guaranteed Magneto Parts Co., 210 West 54th Street, *New York City.*

HIGGINS, HARRY A. (M) factory manager and engineer, Long Mfg. Co., East Grand Boulevard and Cameron Avenue, *Detroit.*

HOLBROOK, FRANK (M) chief inspector, Russel Motor Axle Co., North Detroit, (mail) 2331 Grand Boulevard East, *Detroit.*

HOOD, CLIFFORD F. (A) superintendent, electric cable works, American Steel & Wire Co., *Worcester, Mass.,* (mail) 738 Main Street.

HOWELL, KIMBARK JEFFREY (E S) 70 Trumbull Street, *New Haven, Conn.*

HUNT, WILLIAM H., JR. (A) automotive engineer, Ordnance Office, Ninth Corps Area, *San Francisco,* (mail) 804 Sante Fe Building.

JONTZ, G. F. (M) chief inspector, tractor works, Moline Plow Co., *Rock Island, Ill.,* (mail) 806 44th Street.

KEEFE, W. S. (A) secretary, Gill Mfg. Co., 8300 South Chicago Avenue, *Chicago.*

KING, W. GRIFFIN (J) general sales department, Aluminum Manufactures, Inc., *Cleveland,* (mail) 2289 St. James Parkway.

KINGSNORTH, HERMAN (S M) director of instruction, Marine Corps, Washington, (mail) P. O. Box 192, *Quantico, Va.*

KNAPP, ARCHER L. (M) automobile body engineer, Packard Motor Car Co., *Detroit,* (mail) 2156 Cadillac Avenue.

LAGUIRE, RAYMOND F. (J) laboratory assistant, Joseph Tracy, New York City; (mail) 89 Prospect Place, *Rutherford, N. J.*

LANDANE, GEORGE F. (A) district manager, Duplex Engine Governor Co., Inc., Brooklyn, N. Y., (mail) Room 712, Steger Building, 28 East Jackson Boulevard, *Chicago.*

LANE, KENNETH M. (J) aeronautical engineer, Dayton Wright Co., *Dayton, Ohio,* (mail) 640 Ellerton Avenue.

LANGHAMMER, A. J. (M) industrial engineer, Thompson & Worley, *Detroit,* (mail), 271 Marston Avenue.

LARSON, J. LYMAN (A) instructor, University Farm School, University of Minnesota, *St. Paul, Minn.,* (mail) Division of Agricultural Engineering, Room 203, Farm School.

LEET, ALBERT B. (M) chief draftsman, Rockford Drilling Machine Co., *Rockford, Ill.,* (mail) 1317 North Main Street.

LEYERLE, FRANK J. (A) assistant to president, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

LINNEY, WILLIAM A. (A) foreman, dynamics laboratory, Aluminum Manufactures, Inc., *Cleveland,* (mail) 2140 Broadview Road.

LORING, THOMAS W. (J) body engineer, Republic Motor Truck Co., Inc., *Alma, Mich.,* (mail) 812 North Court Street.

LUDWICK, H. V. (M) chief engineer, Budd Wheel Corporation, Philadelphia, (mail) 203 Park Lane, *Trenton, N. J.*

MCKENNA, A. W. (A) superintendent, Osgood Bradley Car Co., *Worcester, Mass.,* (mail) 465 Park Avenue.

MALKMUS, GEORGE A. (J) instructor, Rahe Auto & Tractor School Co., Ninth and Walnut Streets, *Cincinnati.*

MALOON, EARL B. (J) draftsman, C. L. Best Gas Tractor Co., San Leandro, Cal., (mail) 2587 35th Avenue, *Oakland, Cal.*

MEERBECK, AUGUST F. (A) superintendent construction, Osgood Bradley Car Co., *Worcester, Mass.,* (mail) Hotel Standish.

MEYER, GEORGE L. N. (J) secretary, George J. Meyer Mfg. Co., *Milwaukee,* (mail), 796 Marietta Avenue.

MILLER, G. REYNOLDS (A) general purchasing agent, Daniels Motor Co., *Reading, Pa.*

MUNSON, WILLIAM C. (A) sales engineer, Russell Mfg. Co., Middleton, Conn., (mail) 162 East Jefferson Avenue, *Detroit.*

MURPHY, THOMAS A. (A) district sales engineer, Universal Battery Co., *Chicago,* (mail) 2008 Birchwood Avenue.

MYERS, WILLIAM M. (M) experimental engineer, Johnson Co., *Detroit* (mail), 1459 Clairmount Avenue.

NANSEN, WILLIAM D. (J) draftsman, Moon Motor Car Co., *St. Louis,* (mail) 901 Dover Place.

OLIVIER, H. C. (A) mechanical engineer, Hooistraat 1, *Den Haag, Holland.*

PANNELL, ERNEST V. (M) consulting engineer, British Aluminum Co., Ltd., 165 Broadway, *New York City.*

PARKER, HUMPHREY F. (M) assistant engineer and physicist, Bureau of Standards, *Washington,* (mail) Room 107 West, Bureau of Standards.

PLEASONTON, F. R. (A) general manager, Parish Mfg. Corporation, *Reading, Pa.*

PRESTON, VICTOR (M) chief engineer, Hayes Ionia Co., *Grand Rapids, Mich.*

PRINKEY, JOHN WARD (M) engineer, Dayton Engineering Laboratories Co., *Dayton, Ohio,* (mail) 1204 Vernon Drive.

PROPER, LESLIE E. (J) body designer, Durant Motors, Inc., 560 Jackson Avenue, *Long Island City, N. Y.*

REDFIELD, C. S. (M) manager, development department, Dunlap Tire & Rubber Corporation of America, *Buffalo, N. Y.,* (mail) 48 Irving Place.

RODE, EDWARD W. P. (A) service manager, Buffalo Sterling Co., Buffalo, (mail) 823 Northampton Street.

ROE, WALTER H. (M) mechanical and consulting engineer, Spayth Block, *Tiffin, Ohio.*

SELLSTROM, ELMER W. (M) assistant general manager, Dahlstrom Metallic Door Co., *Jamestown, N. Y.*

SHAFER, WILLIAM H. (M) secretary and superintendent, Ahrens-Fox Fire Engine Co., Cincinnati, (mail) 2879 Erie Avenue, *Hyde Park, Cincinnati.*

SMALL, A. R. (A) vice-president and superintendent label service, Underwriters' Laboratories, Inc., *Chicago,* (mail) 401 Melrose Street.

SMALL, R. C. (M) works manager, Teetor-Hartley Motor Corporation, *Hagerstown, Ind.*

SNYDER, FLOYD E. (A) chief inspector, Stutz Motor Car Co., *Indianapolis,* (mail) 1301 Parker Avenue.

SOUTHARD, SEWALL CLARKE (E S) P. O. Box 521, *Angola, Ind.*

STANTON, RICHARD F. V. (J) engineer in charge of planning department Pratt & Whitney Co., *Hartford, Conn.,* (mail) 282 Laurel Street.

STEADMAN, CLAUDE A. (J) chassis and engine layout, C. H. Wills Co., *Marysville, Mich.,* (mail) Box 41.

STEVENS, R. L. (J) service engineer, United Motors Service, Inc., 3044 West Grand Boulevard, *Detroit.*

STEVENSON, ARTHUR (A) president, American Automotive School, 101 North Haskell Avenue, *Dallas, Tex.*

STEWART, JAMES L. (A) vice-president and general manager, Thomart Motor Co., *Akron, Ohio.*

STROM, G. A. (A) chief engineer, Erie Motor Truck Mfg. Co., Erie, Pa., (mail) 1054 Priestly Avenue, *Lawrence Park, Pa.*

TIGAR, M. GEORGE (A) treasurer and general manager, M. George Tigar Bearings Co., Inc., 18 West 62nd Street, *New York City.*

TORRESEN, CAREL THEODORE (M) chief draftsman, tank, trailer and tractor division, Ordnance Department, *Cleveland,* (mail) 2072 East 46th Street.

UPTON, G. B. (M) professor, experimental engineering, Cornell University, *Ithaca, N. Y.,* (mail) 11 Central Avenue.

VON THADEN, HERBERT (J) mechanical and aeronautical engineer, 52 Massachusetts Avenue, *Cambridge, Mass.*

WARSHAW, NATHANIEL (M) chief engineer, Murray & Tregurtha Corporation, Atlantic, Mass., (mail) 11 Bedford Street, *Quincy, Mass.*

WEBB, BERTRAM B. (J) draftsman, Whitehead & Kales Co., 1263 West Canfield Avenue, *Detroit.*

WEBER, EUGENE A. (M) chief engineer, Gardner Motor Co., Inc., St. Louis, (mail) 1051 Tuxedo Boulevard, *Webster Groves, Mo.*

WERNER, J. F. (M) body engineer, Kissel Motor Car Co., *Hartford, Wis.,* (mail) 330 East Loos Street.

WEYL, PIERCE A. (J) machine engineer, Anderson Foundry & Machine Co., *Anderson, Ind.,* (mail) 132 West 13th Street.

WHEATLEY, WILLIAM BALLANTINE (J) student, electrical engineering, Pratt Institute, *Brooklyn, N. Y.,* (mail) 223 Ryerson Street.

WHITING, LIEUT. EDMUND ALDEN (S M) inspector of naval aircraft, Aeromarine Plane & Motor Co., *Keyport, N. J.,* (mail) Cedar Street.

WILLIAMS, CHESTER P. (A) sales engineer, Northway Motors Sales Co., Boston, (mail) 33 Florence St., *Natick, Mass.*

WILLIAMS, J. J. (M) general production superintendent, Federal Rubber Co., Cudahy, Wis., (mail) Apartment 611, 203 Juneau Avenue, *Milwaukee.*

WITTER, HARRY L. (A) lubrication engineer, Standard Oil Co., *Detroit,* (mail) 2688 Columbus Avenue.

WOOD, E. ELLSWORTH, JR. (A) engineering, Miniature Incandescent Lamp Corporation, 95 Eighth Avenue, *Newark, N. J.*

WREAKS, HUGH T. (A) Detroit manager, Boston Insulated Wire & Cable Co., 404 East Jefferson, *Detroit.*

YOUNGS, ARTHUR (A) manager, Youngs & Co., Inc., *Newburgh, N. Y.,* (mail) 199 North Miller Street.

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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The Summer Meeting

THE Summer Meeting of 1921 at West Baden, May 24 to 28, was a distinct success according to the sentiments voiced by a large majority of the 700 members and guests in attendance. Weather conditions were not exactly ideal, but in spite of the handicaps resulting from postponement of sports contests, due to rain, the outdoor program was completed and everyone seemed to have their anticipated share in the fun. The facilities at West Baden lend themselves admirably to almost any weather and this fortunate condition, coupled with the arduous labors of the group of men in charge of the recreational features of the program, is responsible for the completion of the sports before the close of the meeting.

The extent and nature of the attendance were most gratifying to those who spent the spring arranging the many details of the meeting, which is a very diversified undertaking. All branches of the industry were represented and a great many of the faces have grown familiar by their periodical reappearance at the Society gatherings. For pure goodfellowship and congenial spirit it is difficult to find the equal of the Summer Meeting. The enthusiastic greetings and handshakes in the early stages of each annual summer get-together remind one of the atmosphere which prevails at college reunions. There is nothing more beneficial to an industry with problems to solve than the opportunity presented at assemblies of this character for mind-to-mind discussion of the obstacles to be overcome, whether they be engineering, commercial or financial. The industry's belief in this fact is best evidenced by the undiminished support of the 1921 Summer Meeting when economic conditions were not all that might have been desired.

Sports and Recreation

The sports program was the most popular feature of the meeting, as in past summers. The direction of the several contests was ably handled by Howard A. Coffin, who deserves unusual credit for his untiring efforts and enthusiasm. Mr. Coffin had the work well organized in groups, each of which was directed by one of his assistants. The golf tournament which Earl Roberts conducted in commendable style, seemed the most popular of the tournaments. Except for the rainy period on Wednesday and Thursday, the course was crowded with the followers of the mashie, putter and niblick. There were 99 contenders for the Society championship in the qualifying round. On Thursday the field narrowed down to 16 and in the finals on Saturday morning John Watson carried off the honors with Thomas Doe as runner-up. A flag tournament was played on Friday for those who failed to qualify for the championship flight. This was won by E. A. Ross.

The Atrium of the Hotel during the Clock-Golf Contest

The putting contest was won by J. E. Schipper. There were so many ladies interested in golf at this summer's meeting that a very exciting match was arranged for them by the committee. This was won by Miss Roberta Large, with Mrs. Jack Gray runner-up. Mrs. H. G. Jackson outdistanced the other ladies in the driving contest and won that event.

The singles and doubles tennis tournament was conducted by Stanley E. Bates. Second to golf in number of participants, but not in enthusiasm, this tournament had 32 entries in the singles and 12 teams in the doubles, the largest field recorded at a Summer Meeting. The doubles tournament furnished many spirited matches, Stanley E. Bates and W. J. Buettner winning the finals from H. M. Crane and C. F. Clarkson. The singles championship was not decided until Saturday afternoon, when C. F. Clarkson defeated W. J. Buettner (6-1, 6-1). Unfortunately the weather eliminated all chance of playing the Inter-Section baseball series, which had been laid out by Geo. H. Hunt, but a game was arranged for Friday afternoon to console those diamond artists who had spent weeks training for the anticipated fray. The

appropriate names, Gasolines and Kerosenes, were given the two nines, the latter showing the highest brake mean effective pressure in the ratio of 12 to 2. The personnel was as follows:

Kerosenes		*Gasolines*
L. C. Hill	Pitcher	J. G. Vincent
F. G. Whittington	Catcher	J. L. Carey
V. E. Clark	1st base	R. G. Bradley
L. P. Jones	2nd base	G. A. Christopher
K. M. Lane	3rd base	B. W. Brodt
George Hunt	Shortstop	George Sevale
V. Tomlinson	Left field	W. E. Dolan
J. C. Ferguson	Right field	Robert Wilson
Mortimer Frankel	Center field	Herbert Saurer

The trophies for the indoor and the outdoor baseball Section championships will necessarily be retained by their present holders until 1922, when it is hoped that J. Pluvius will show a better spirit of cooperation.

The setting for the races and field events was most picturesque, everyone not busy in the golf tournament or trapshooting gathering in the stand enclosing the athletic field to view the engineer athletes in action. All of the events provided exciting finishes and the humorous antics of the participants in the several stunt races kept the crowd thoroughly amused. The outstanding feature of the field day, at least in point of applause, was the ladies' baseball throwing contest in which the Misses Norma and Ruth Porter outdistanced all competitors and even made it difficult for the judges to return their throws.

In addition to the members of the Sports Committee, the following assisted in making the field day a success: B. G. Koether, head judge of track events; Mark Smith, head judge of field events; J. J. O'Neill, C. R. Bissel, clerks of the course, and C. B. Veal, starter.

W. H. Pratt shouldered the responsibility of the bowling and quoits events and succeeded in conducting several very interesting contests. Mr. Pratt showed the greatest skill in ringing the peg and won the men's quoits, 15-6 and 15-12, from W. L. McGrath. Mrs. Lon Smith won the ladies' quoits from Mrs. Howard A. Coffin, 11-3 and 11-4. In the men's bowling tournament F. J. Richardson carried off first honors, F. A. Clawson was second and H. F. Sauer third. Mrs. T. Milton won the ladies' bowling contest from Mrs. A. H. Bartsch.

The ladies had plenty of diversion provided for them during the hours when the members were busy in the technical meetings. Howard Spohn officiated as director of the card parties, in addition to acting as announcer and chairman of the dance committee. Three five-hundred parties were played, the first prizes being won by Mrs. George Goddard, Mrs. H. R. McMahon and Mrs. Frank B. Ruoff. In the two bridge parties Mrs. H. L. Horning and Mrs. F. S. Slocum proved most expert and won the first prizes. The ladies' indoor putting-contest in the center of the great atrium of the hotel proved to be one of the prettiest settings of the meeting. Some 200 of the folks were seated in a great circle, in the center of which the clock-golf course had been laid out. It was truly an impressive picture. Mrs. H. L. Horning won this event with the excellent score of 18, although closely pressed by Mrs. H. R. McMahon, with a 19. Mrs. H. G. Jackson took third after playing off a tie with Mrs. David Beecroft. The outdoor clock-golf was won by Mrs. H. A. Coffin, with Mrs. A. J. Poole, Mrs. Geo. A. Kraus and Mrs. David Beecroft placed second, third and fourth, respectively.

The croquet excited the usual interest among the ladies and after several closely contested matches Mrs. V. E. Clark won the singles and Mrs. Howard A. Coffin and Mrs. H. T. Ewald the doubles.

The trapshooting contest, arranged and conducted by Lon R. Smith, proved to be the one in which the greatest skill was demonstrated by the engineer athletes and sportsmen. When four shoots are won in four days with the high man breaking 49 out of 50 pigeons, it certainly is a noteworthy accomplishment. The sharp-shooters who set this unusual pace are J. A. Fesler, D. F. Fesler and W. H. Miller. In the finals for the Society championship, J. A. Fesler repeated his performance in the preliminary shoots and won with 49 out of a possible 50.

To describe the spacious and beautiful atrium each evening with its many soft lights, twirling dancers and brilliant, colorful settings is beyond accomplishment. The medley of frivolity, laughter and music will long rest in the memory of those fortunate enough to witness the extraordinary scenes. No other phase of the meeting excited greater comment. Seldom have the ladies of the Society danced to music so rhythmic, soft and pleasing. We know that next year's meeting will present a large attendance of the gentler sex, for everyone seemed to be so thoroughly pleased every hour of the day. The dance contest attracted many graceful entrants and it was a most difficult task to select the one entitled to first prize. Miss Estelle Brion, who had won the contest twice previously, was awarded the cup with a very narrow margin over Miss Roberta Large, who received second prize. The prizes for all of the athletic contests were awarded just after the dance contest by Chairman Howard A. Coffin.

Motion pictures were shown each evening in the atrium, a variety being selected which was certain to suit the tastes of everyone. The production of gasoline and other petroleum products was illustrated in a most instructive manner by a six-reel film, presented through the courtesy of the Associated Oil Co. Stephen S. Johnson gave a very entertaining lecture on the natural beauties of some of the national parks in the West.

The customary Section stunts were received most enthusiastically by somewhat skeptical audiences. Dr. Einstein, in the person of C. T. Myers, explained in detail the inner sphere of the popular hydrocarbons, with the assistance of M. C. Horine and C. R. Bissel, who manipulated uncanny apparatus and agitated colorful chemicals to illustrate the novel theories fostered by the Metropolitan Section. The Dayton Section built up an atmosphere of mystery around a helicopter which it had intended to fly but before the members had an opportunity to view the gyrations, the Section put on a private exhibition for the West Baden natives, thus spoiling the party. The Cleveland crowd decided to center their efforts in the circus ring, and the reception which greeted their free peanuts, freaks, clowns and acrobats indicated that the audience was more than pleased. L. L. Williams deserves honorable mention for creating this diminutive Ringling show.

Indiana night was the most elaborate entertainment provided by the Sections, for Indiana was anxious to impress those outside her borders with the hospitaltiy of the Hoosier State. Appropriate noise-makers, balloons and paper hats were distributed before the dinner to add the carnival touch. Thomas Taggart spoke briefly, and the Hoosier poet, Bill Hershell, entertained with tales and verse. Richard Lieber, of the Indiana Conservation Bureau, gave an excellent address. The real hit of the

AUTHORS OF PAPERS AND SOCIETY OFFICERS

C. W. Stratford — W. E. Lay — W. S. James — G. P. Dorris

B. B. Bachman — J. G. Vincent

David Beecroft

C. F. Clarkson — C. F. Scott

Herbert Chase — F. C. Ziesenheim — H. L. Horning — V. E. Clark

affair, however, was Mark Smith who impersonated an Italian officer and presented a most interesting engineering talk on nothing in particular. Some who were present still deplore the discourtesy accorded the foreign guest by those who realized that the presentation was a hoax. Lon Smith, B. F. Kelly and all others of Indiana who arranged this enjoyable evening are to be congratulated on its success.

Standards Committee Reports

The reports submitted by 10 Divisions of the Standards Committee included 25 subjects with reference to which recommendations had been formulated since the Annual Meeting of the Society held in January. Nineteen of the recommendations were accepted as submitted, while four were approved in amended form and two were referred back to the Divisions.

The two recommendations referred back related to ball studs, reported by the Engine Division, and rating of storage batteries, submitted by the Isolated Electric Lighting Plant Division. The report of the latter was made in two sections, referring respectively to the cancellation of the present standard and the substitution therefor of a new method of rating batteries for service in connection with isolated electric lighting and power plants. The first section of the report was approved, but it was thought that the second section should be reconsidered by the division and farm light and powerplant manufacturers with a view to bringing about greater harmony of opinion concerning a suitable standard.

The division report, as accepted by the Standards Committee and approved at the Council and the Society meetings, will be published in complete detail in the July issue of The Journal for the purpose of taking a letter ballot on their adoption, all of the full members of the Society being entitled to vote.

Nomination of 1922 Officers

B. B. Bachman was nominated to serve as President of the Society for the next calendar year by the Nominating Committee, which was completed and organized at the West Baden meeting. The committee reported the following other consenting nominees for the elective offices next falling vacant under the constitution, i.e., after the 1922 Annual Meeting of the Society:

First Vice-President—J. V. Whitbeck
Second Vice-President, representing motor-car engineering—F. E. Watts
Second Vice-President, representing tractor engineering—O. W. Young
Second Vice-President, representing aeronautic engineering—V. E. Clark
Second Vice-President, representing marine engineering—H. E. Morton
Second Vice-President, representing stationary internal-combustion engineering—C. B. Segner
Councilors (to serve during 1922 and 1923)—H. M. Crane, Lon R. Smith and C. F. Scott
Councilor (to serve during 1922)—W. R. Strickland
Treasurer—C. B. Whittelsey

The members of the 1921 Council who will hold over during 1922, are David Beecroft as past-president and Councilors W. A. Brush and F. W. Davis.

The Nominating Committee was constituted of F. M. Germane (chairman), Pennsylvania Section; L. W. Rosenthal, Boston Section; H. R. Corse, Buffalo Section; A. E. Jackman, Cleveland Section; Thomas Midgley, Jr., Dayton Section; Russell Huff, Detroit Section; H. W. Slauson, Metropolitan Section; Foree Bain, Mid-West Section; A. W. Scarratt, Minneapolis Section; Dr. H. C. Dickinson, Washington Section; G. P. Dorris, R. E. Northway and E. A. Sperry, members at large, and M. A. Smith (secretary), Indiana Section. This was the annual Nominating Committee, provided for by the Society's constitution, under which 20 or more members entitled to vote may constitute themselves a special Nominating Committee, with the same power as the Annual Nominating Committee. The by-laws of the Society provide that a special Nominating Committee, if organized, shall on or before Nov. 15 present to the Secretary of the Society the names of the candidates nominated by it for the elective offices next falling vacant, together with the written consent of each.

Presidential Address

President Beecroft delivered in an eloquent manner an address on current domestic and foreign automotive trade conditions and on the proposed work of the Research Department of the society. He stated with emphasis that no time could be more appropriate than the present for the commencement of such work. He pointed out at some length the fundamental value of and necessity for intensive research and dissemination of new and old facts in proper form.

Treasurer's Report

The report of the treasurer showed that the total assets of the society were $207,522.44 on April 30, 1921, with accounts payable of $9,377.23; that the income of the society for the first seven months of the present fiscal year had been $6,137.44 in excess of the expenses for the same period, and that a comparison of income and expense for the first six months of the present fiscal year with the corresponding figures for last year indicated very little change in the total figures, which was considered to be very gratifying in view of current industrial conditions.

Membership Growth

The Membership Committee reported that 324 applications for membership had been received during the first four months of this calendar year; the corresponding figures for 1920 being 406. The number enrolled on the roster of the Society on April 30, 1920, and April 30, 1921, were 4798 and 5468 respectively.

The Sections

The Sections Committee submitted a report on the increased membership in and greater value of the work of the sections. The committee met the council and a large number of the sections' officers at luncheon and discussed plans for the future. It is believed that much good will result from this meeting.

Technical Sessions

Many favorable comments were heard on the character of the papers presented at the technical sessions. The general impression seemed to prevail that the subjects covered were presented in admirable fashion and in a manner beneficial to all of those who took an interest in this phase of the meeting. The discussions were generally terse and pertinent, and the chairmen in charge of the sessions should be commended for the manner in which they were conducted.

The paper by L. E. Pierce and G. J. Mead on Aviation

AMONG THOSE WHO TOOK A PROMINENT PART IN THE MEETING WERE

W. G. Wall F. M. Germane O. C. Berry H. C. Buffington
Alfred Reeves M. L. Heminway
H. M. Crane
H. R. Corse H. C. Dickinson
E. A. Johnston Robert Wilson Thomas Midgley, Jr. A. W. Scarratt

Powerplant Development aroused much interesting discussion. Mr. Pierce, who read the paper, stressed the necessity of better installations of the powerplant to eliminate the engine failures in the air which generally result from minor defects in the operation of the gasoline, cooling or lubrication systems, independent of the engine itself. A very interesting discussion was given by Elmer Sperry, who urged the study of the Diesel engine as a possible powerplant for the airplane of the future, particularly in view of its burning a fuel whose low volatility reduced the fire hazard. The present status of commercial air transportation was discussed frankly by V. E. Clark in his paper on Air Transportation and the Business Man. This paper was welcomed by the members as representing one of the most candid expositions ever given of the obstacles which are at present impeding the progress of commercial aviation. It was felt that discussions of this sort would prove most constructive in the foundation of commercial aviation on a sound economic basis. Mr. Clark mentioned the need for Federal control for commercial aviation in his paper, and this subject was discussed very thoroughly by S. H. Philbin, who presented the matter from a legal standpoint. J. G. Vincent presided at the aeronautic session and contributed considerable discussion.

The matter of transport engineering education was discussed in a paper by C. J. Tilden, which was read by Alfred Reeves. Mr. Tilden emphasized the need of providing a proper curriculum in our universities in order that men could be given an education which would fit them for the practical management of motor-transport companies. A. T. Goldbeck of the Bureau of Public Roads stressed the need for better cooperation between the highway engineer, who builds and maintains the nation's roads, and the automotive engineer, who designs most of the vehicles which use them. Mr. Goldbeck believed that it would eventually become necessary for the automotive engineer to lessen the weight concentrated on each individual wheel by increasing the number of wheels in large motor trucks used for highway transport. At the same time he recognized the responsibility of the highway engineer for improving the design of highways to carry the larger loads imposed upon them by modern motor trucks. Mr. Goldbeck suggested that the Society appoint a responsible committee of automotive engineers to cooperate with the Association of State Highway Officials and it was voted that this be acted on by the President of the Society.

H. M. Crane, chairman of the Research Committee, presided at the general research session. The paper by L. A. Hawkins on Industrial Research was read by title. C. W. Stratford gave a very interesting and educational talk on the subject of lubrication and discussed some of the research study on lubrication problems that has been done under his direction on the Pacific coast. The paper by Herbert Chase on Clutch Design aroused considerable interest, and Mr. Chase was commended by the members for gathering together such a quantity of valuable design data and information. The members expressed the hope that similar papers would be prepared in the future on other major units of the motor car. W. E. Lay described the plan recently inaugurated at the University of Michigan to place the laboratory and personnel facilities of the university at the disposal of industrial organizations to further promote advanced research study.

The Combustion Research Session produced three extremely valuable papers. Judging from the reception accorded it, H. L. Horning's paper on Turbulence seemed to be one of the most important of the week. The advantages of maintaining a turbulent mixture in the combustion-chamber of an automotive engine were enumerated by Mr. Horning. Forms of combustion-chambers which tended to produce turbulence in the charge were shown and the improvement in engineering performance resulting from this turbulence set forth. C. A. French presented a hypothesis on the action of flame and combustion in internal-combustion engines. This produced active discussion on the part of the members, much of which will prove of value in the further study of flame phenomena. An abstract of Sir Dugald Clerk's paper on Cylinder Actions in Gas and Gasoline Engines was read in very able fashion by Prof. Daniel Roesch. It was to be regretted that illness prevented the attendance of Sir Dugald Clerk in person, for the members had looked forward to the occasion of his being with us at the Summer Meeting. The paper outlined in a comprehensive manner the life study of the internal-combustion engine which has been made by the author and it will serve as an excellent reference work for those engineers who are interested in the fundamental thermodynamic theory of the present-day automotive engine. Thomas Midgley, Jr., made a capable chairman for this meeting, particularly in view of his personal achievements in the study of combustion problems.

The discussion during the Fuel Research Session was probably more active than that had in any other session. This session was directed by O. C. Berry, who has spent considerable time in the study of carburetion and the fuel problem. The possibility of developing a Diesel or high-compression type of engine for adaption to automotive apparatus was discussed thoroughly in the paper presented by F. C. Ziesenheim. Mr. Ziesenheim's analysis of the fuel problem led him to the conclusion that this type of engine should receive careful study as one of the determinant factors in deferring the fuel shortage. George P. Dorris described a manifold developed on somewhat new lines for the purpose of trapping and distilling over the higher ends of modern engine fuels, thus preventing their entering the combustion-chamber in liquid form and either passing out of the exhaust unburned or draining into the crankcase and diluting the lubricating oil. A very comprehensive paper, enumerating in detail the many elements affecting automotive fuel economy, was presented by W. S. James of the Bureau of Standards. Appendices were contributed by Dr. H. C. Dickinson, S. W. Sparrow, and by R. L. Wales. This paper was intended as more of a summation of the work that has been done on the fuel problem than as a presentation of any new theories or experiments. Dr. Dickinson's appendix on Detonation was particularly commended by the audience. In the discussion following the presentation of the paper, Prof. Robert Wilson of the Massachusetts Institute of Technology described the method he has used in determining the dew-point of gasoline. He also illustrated with slides the value of these data to the engineer who is troubled with manifold and carburetion problems. Thomas Midgley, Jr., informed the members of the recent discovery of a fuel dope or alternative which was much more effective in eliminating fuel knock than any used previously. Due to the effectiveness of this material, only a small percentage need be added to the fuel, and Mr. Midgley felt that this would eventually lead to higher compressions in Otto-cycle engines and enable them to attain thermal efficiencies comparable to those of the Diesel engine.

Cylinder Actions in Gas and Gasoline Engines

By Sir Dugald Clerk[1]

Semi-Annual Meeting Paper *Illustrated with* Charts and Drawings

I HAVE read the excellent papers of A. L. Nelson[2] and Thomas Midgley, Jr.[3] and that of C. A. Woodbury,[4] H. A. Lewis and A. T. Canby with much interest and approval. I have gathered from them that you are experiencing the same difficulties with regard to oil fuel in America as we are in England. I agree with the authors of the last paper that it is necessary to turn attention to using other fuels such as kerosene, benzol and alcohol, and also to increase the engine efficiency when using the existing standard fuel.

You have been good enough to invite me to read a paper before you on the actions within the cylinder of a gasoline engine; hence the title chosen by me. My experimental work has been mostly performed on gas engines of relatively large cylinder-diameter, but many observers have found the same phenomena in gasoline engine work. I have also experimented with many gasoline engines, but it is much easier to study diagrams and flame effects with the slower-running gas engine.

I shall begin with a short account of the principal actions common to all internal-combustion engines, and then proceed to a more detailed account of the experiments which have been made to develop the theory and establish the properties of the flame working fluid of those engines.

Short Statement of Cylinder Actions

During the suction stroke of the ordinary four-stroke internal-combustion engine, the charge of air and gas or air and gasoline vapor and spray flows through the valve opening at a velocity which usually exceeds 100 ft. per sec. or 68 m.p.h. It enters the cylinder and fills it with a mixture of the fresh charge and the exhaust gas remaining from the last power stroke, all in a state of violent agitation or eddying. This agitation dies down in time, but at the end of the compression stroke, just before ignition, there remains a considerable internal motion. In a gas engine of 9-in. cylinder diameter and 17-in. stroke tested by me I found the residual turbulence at that point sufficient to increase the velocity of the spread of the flame after ignition to three times that which occurs in a still mixture of the same composition. As this state depends on the piston speed, an increase of the piston speed causes an increase of the initial turbulence, and hence a more rapid spread of flame to meet the increased rate of piston movement. Without this automatic change of ignition rate the high-piston-speed gasoline engine would have been impossible.

During the suction stroke the mixed charge passes through the valve opening at the temperature of the atmosphere, in the case of the gas engine, but somewhat below it in the usual case of the gasoline engine, due to evaporation of the liquid fuel; and as the valves and piston-end and cylinder walls are hotter than the charge, heat flows into it, and whenever the charge is complete its temperature is raised in a gas engine to about 100 deg. cent. (212 deg. fahr.), partly because of the heat-flow into the charge and partly because the cool charge is mixed with a certain proportion of hot exhaust-gases at the beginning of the suction stroke, whose temperature is about 500 deg. cent. (932 deg. fahr.)

This mixture at the suction temperature of 100 deg. cent. (212 deg. fahr.), when compressed in the engine mentioned which has a 5.5 compression-ratio, rises to about 360 deg. cent. (680 deg. fahr.) at a pressure of about 120 lb. per sq. in. above atmosphere. On ignition the temperature rises to a maximum of 1600 deg. cent. (2912 deg. fahr.) in about 1/40 sec., and the maximum corresponding pressure becomes about 330 lb. per sq. in. above atmosphere at nearly 1/20 of the forward stroke. The speed of this engine is 200 r.p.m., so that one revolution takes 0.30 sec. and a single stroke 0.15 sec. Had turbulence been absent at the time of ignition it would have required nearly 0.1 sec. to complete the spread of the flame and the maximum temperature would not have been attained till half stroke forward.

The time of inflammation necessary for a gasoline engine running at 1200 r.p.m. is much shorter; at this speed it should not exceed 1/120 sec., and at higher speeds much greater rapidity is required to give reasonable efficiency. The late Dr. W. Watson gave 1/300 sec. as the time in a small gasoline engine tested by him. Assuming the flame to travel 4 in. to fill the small cylinder, then its velocity must be 100 ft. per sec.

The flame velocity in an engine varies with the suction velocity and also with the gaseous or liquid fuel employed. Thus in one large cylinder gas engine of 22-in. diameter and 34-in. stroke, running at 160 r.p.m., the explosion period with Mond gas, suction gas and coal gas was respectively 1/21, 1/24, and 1/38 sec., and the corresponding flame velocity 47, 54 and 85 ft. per sec. The inlet velocity was 160 ft. per sec. In a smaller gas engine the inlet velocity was 100 ft. per sec. and the flame velocity 37 ft. per sec. With the richest mixtures used in gas and gasoline engines the flame temperature rises as a maximum value to 2000 deg. cent. (3632 deg. fahr.), although one set of experiments made by Professors Dalby and Callendar reached 2400 deg. cent. (4352 deg. fahr.). In both gas and gasoline engines the rate of flame transmission with turbulence varies from 30 to 100 ft. per sec.

When the spark ignition is placed in the center of the combustion space open to the piston without pockets, the ignition starts as a small hemisphere and spreads for-

[1] Past-President, Institution of Automobile Engineers.

[2] Fuel Problem in Relation to Engineering Viewpoint, published in The Journal, February, 1921, p. 101.

[3] Combustion of Fuels in Internal-Combustion Engines, published in The Journal, December, 1920, p. 489.

[4] Nature of Flame Movement in a Closed Cylinder, published in The Journal, March, 1921, p. 209.

ward and outward in all directions; the flame-front travels somewhat slowly and compresses the mixture in front of it toward the cylinder walls and the piston. The mixture is thus submitted to further heating by compression before the mass of it is ignited. As the flame continues to spread, the portion first ignited near the spark-plug is subject to compression also, so that as the hemisphere expands compression proceeds on both sides of the flame boundary, the hot gases at first passing forward into the mixture as in expanding at constant pressure, and later hot gases flow back from the flame-front as well as forward, so that the flame nearest the igniter sustains the longest period of compression and is heated above the temperature of explosion by nearly adiabatic compression. This recompression is important, as it emphasizes the necessity for thorough cooling of the spark-plug so as to avoid overheating and preignition. The late Professor Hopkinson discovered this interesting temperature-rise in 1906 by experiments made with optical indicator and platinum wire thermometer by means of a large explosion vessel. Turbulence modifies the action, but it must occur in all usual designs of gas and gasoline engines. When the flame passes through the whole combustion space and reaches the walls, the temperature at the spark-plug end may be as high as 500 deg. cent. (932 deg. fahr.) above the temperature at the walls, notwithstanding that this part is the last ignited and has lost but little heat. When the flame reaches the enclosing walls and every part is filled with flame, the combustion is not yet complete. In some gaseous explosions the flame fills the whole space before the pressure completes its rise. This was inferred by me in 1885 from gaseous explosion experiments made with my first explosion apparatus, but it was definitely proved to be the case by Hopkinson's experiments in 1906 mentioned above. Hopkinson found that 85 per cent of the total pressure-rise had occurred when the flame filled the vessel, but 15 per cent further rise completed the explosion period.

In Hopkinson's experiments with a mixture composed of 1 part gas and 9 parts air, the rate of flame propagation was about 6 ft. per sec. During the pressure-rise due to the spread of the flame, heat loss from the flame at once begins, because of radiation, and the radiation increases with the general temperature-rise; conduction and convection also then act, so that when maximum mean-temperature is attained, a portion of the heat of the explosion has already passed to the cylinder walls and water-jacket. This portion was much underestimated by the earlier experimenters. On this important subject Hopkinson, with his pupil David, now Professor David, of the University College of Cardiff, made ingenious experiments in closed vessels with a metal strip calorimeter and a bolometer, measuring the radiation passing through a fluorite window to the instrument. Radiation was shown to have a most important effect.

David has experimented with mixtures of coal gas and air in a closed vessel of about 12-in. diameter and 12-in. length. Three mixtures were used; 15, 12.4 and 9.7 per cent by volume of gas. At the moment of maximum temperature of the explosion he found the distribution of the energy of combustion of the gas present to be as given in Table 1.

TABLE 1—DISTRIBUTION OF THE ENERGY OF GASEOUS EXPLOSIONS AT THE MOMENT OF MAXIMUM TEMPERATURE

Coal Gas in Mixture, per cent	Heat of Combustion, units	Internal Thermal Energy, per cent	Available Chemical Energy, per cent	Heat Loss to Walls of Vessel, per cent
15.0	100	81.0	10.0	9.0
12.4	100	78.0	12.0	10.0
9.7	100	72.5	9.5	18.0

The most economical mixture used in gas engines is about 10 per cent. Assume that mixture to be used in the cylinder we are considering and suppose the losses to be similar to David's losses in still mixture. In that case, when our cylinder has been filled with flame at the highest mean temperature and pressure, the loss from radiation and convection during the explosion period will be 18.0 per cent and there will be 72.5 per cent available as thermal energy, together with 10.0 per cent of heat still to be evolved by chemical action. That is, we have altogether 82.5 per cent of the original total heat of combustion available during the expansion period. Assume that the expansion proceeds during a complete power-stroke; then, in an ordinary gas engine, work is done on the piston and heat is lost to the enclosing walls and temperature falls. The work done and the heat lost by the gases is greatest in the first 30 per cent of the stroke. At the end of the stroke the mean gas-temperature has fallen, when the jacket is hot and the engine has been working at full load, to about 900 to 1100 deg. cent. (1652 to 2012 deg. fahr.). The exhaust-valve then opens and the pressure quickly drops to atmospheric or near it. A considerable portion of the heat of the exhaust gases passes into the water-jacket, so that the temperature and calorimeter measurements of the gases in the exhaust-pipe after leaving the engine give lower temperatures and heat quantities than those proper to the exhaust-gas mass at the end of expansion. During the exhaust stroke the hot gases in the cylinder give up a portion of their heat to the water-jacket. Because of the two losses after expansion the water-jacket temperature-rise does not give a true indication of the heat distribution during explosion and expansion. The friction of the piston in the cylinder, which is the largest mechanical loss in the running of the engine, also generates heat, which passes away partly by the piston and water-jacket, so that from many causes the jacket gets more heat than that due to the thermodynamic action of the engine.

In making running tests under full load it is necessary to allow for all these matters to arrive at a true balance-sheet of heat-disposal by the engine. Even when such a balance-sheet is prepared it is necessary to know the properties of the flame working fluid as to specific heat at various temperatures, the change of volume during combustion and radiation from the engine itself, as well as high-temperature radiation to the cylinder walls from the flame. To know the margin still available for improvement in thermal efficiency it is necessary to determine the maximum efficiency possible, assuming all operations to be perfectly performed without loss of heat in any part of the cycle. For this purpose many valuable investigations were carried out by the late Prof. Bertram Hopkinson and the late Prof. W. Watson. Both men were brilliant and indefatigable experimenters. Professor Hopkinson was in charge of designing and testing new types of airplanes during the war, and our science suffered a sad loss when he was killed when flying from Martlesham Heath Airdrome to London in August 1918. Prof. W. Watson was in charge of poison-gas defence operations in France, and he also died in 1918 as the result of the hardships experienced during the war. His loss was a great blow to the science of the internal-combustion engine. The other English investigators are Professors Callendar, Coker, Dalby, Dixon, Petavel and

Gibson, Mr. Ricardo and Dugald Clerk. These men worked together beginning with the year 1907 as members of the Gaseous Explosions Committee of the British Association, of which I am the present chairman.

Investigations have been made in France by MM. Mallard and Le Chatelier and M. Berthelot and Prof. Aime Witz. Holborn & Henning and Professors Meyer and Junker have made interesting tests in Germany. In America valuable explosion experiments have been made at the Massachusetts Institute of Technology with coal gas and gasoline and air mixtures. The late Prof. R. H. Thurston made important tests and studies of the Brayton petroleum engine and the early Otto engines. Prof. R. C. Carpenter, too, did valuable work in this connection.

As I have devoted much attention also to the limits of thermal efficiency possible in internal-combustion engines I shall, first, discuss rapidly our present efficiencies and knowledge and, secondly, deal with the problems presented by heavier liquid fuels.

The Air Standard

The air standard was first used to compare the thermal efficiencies of internal-combustion engines in a paper[5] read by me in London in 1882. I then proved that in a compression gas engine expanding to the same volume after ignition as before compression and igniting at constant volume the efficiency is determined by atmospheric absolute temperature, and the absolute temperature after compression, and I pointed out that the efficiency is independent of the rise of temperature above the temperature of compression. Whatever be this temperature-rise the proportion of heat converted into work remains the same.

In a book on The Gas Engine published in 1886 I carried the thermodynamic discussion further and deduced the equation for thermal efficiency in terms of compression ratio as

$$E = 1 - (V_c/V_o)\,\gamma - 1$$

where

V_o = the volume in the cylinder before compression

V_c = the volume in the cylinder after adiabatic compression

As now used it is put in the form

$$E = 1 - (1/r)\,\gamma - 1$$

where

$1/r$ = the compression-ratio

The air-standard efficiencies corresponding to values of 0.50 to 0.01 for $1/r$ with heat added at constant volume and expanded to the volume existing before compression are given in Table 2.

TABLE 2—AIR-STANDARD EFFICIENCIES FOR COMPRESSION ENGINES

$1/r$	E
1/2	0.246
1/3	0.360
1/4	0.430
1/5	0.480
1/6	0.510
1/7	0.550
1/10	0.610
1/12	0.630
1/18	0.680
1/20	0.700
1/100	0.850

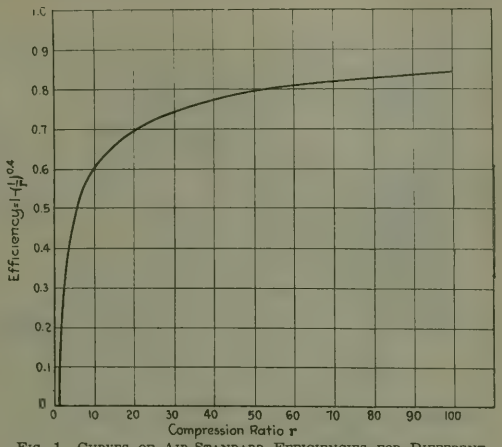

FIG. 1—CURVES OF AIR-STANDARD EFFICIENCIES FOR DIFFERENT COMPRESSION RATIOS

The Institution of Civil Engineers adopted this standard on Dec. 19, 1905, as the result of the investigations of a Committee on Efficiency of Internal-Combustion Engines. The Committee included Professors Unwin, Kennedy and Callendar, and they made tests of three engines of 5.5, 9 and 14-in. diameter cylinders respectively, with practically identical compression-ratios of 1/5.5 approximately, to find the relationship between the air-standard and the actual efficiencies.

The results obtained by dividing the indicated thermal efficiency by the air-standard efficiency were 0.61 for the engine with the 5.5-in. cylinders, 0.65 for the 9-in. and 0.69 for the 14-in.

The engines gave respectively 6, 24 and 60 i.hp. From this it appeared that for a small engine 0.61 of the air-standard value gave the practical result of an engine, allowing for heat losses, while the large engine developing 10 times the power lost less heat and gave 0.69 of the air standard. As the result of many tests it can be accepted that in practice if we calculate the maximum indicated thermal efficiency from the corresponding ratio of the air standard, 0.6 can be taken as the minimum and 0.7 the maximum. Fig. 1 gives curves of air-standard efficiencies from ½ to 1/100 and practical results can be deduced by multiplying by 0.7 and 0.6.

Flame the Actual Working Fluid

It was known in 1905 that the specific heats of the products of combustion are higher than that of air and that they increase with rise of temperature, but the specific heat values were very uncertain. Accordingly I set to work with the largest engine of the Committee and determined the specific heat of the flame in the working cylinder by a new method depending on alternate compression and expansion of the flame within the cylinder. The experiments and calculations occupied two years, and in March 1906 I read a paper[6] at the Royal Society of London giving my results. From the data so determined I prepared a paper for the Institution of Civil Engineers.[7] I then came to the conclusion that in actual operation the 14-in. cylinder engine converted into indicated work 88 per cent of the heat which it possibly

[5] The Theory of the Gas Engine, read before a meeting of the Institution of Civil Engineers held April 4, 1882, and published in the *Proceedings*, vol. 69, p. 220.

[6] The Specific Heat of Heat-Flow from and Other Phenomena of the Working Fluid in the Cylinder of the Internal-Combustion Engine, published in the *Proceedings of the Royal Society*, vol. 77, p. 500.

[7] The Limits of Thermal Efficiency in Internal-Combustion Engines, published in the *Proceedings of the Institution of Civil Engineers*, vol. 169, p. 121.

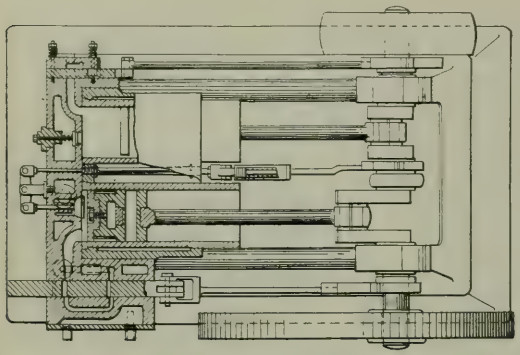

FIG. 2—PLAN VIEW PARTLY IN SECTION OF A TWO-STROKE ENGINE BUILT IN 1878 AND 1879

could have converted into work, considering the properties of the working fluid, as compared with air. Complete suppression of all heat loss would only add 12 per cent to the indicated thermal efficiency of this engine; the value would be 39.5 instead of 34.7 per cent.

The air standard, although most useful in giving comparative results at different ratios of compression, must not be used for reasoning on the possible limits. Thus, the relative efficiency of 0.7, that is, 70 per cent, implies that if the air standard could be attained 30 per cent would be added, while the real value proves to be 12 per cent. It follows from this that the margin of possible improvement on the best results obtained at full load is not great. Little is to be hoped from improvements in reducing heat-flow to the cylinder walls; contrary to what many engineers and inventors believe, the heat loss from the flame to the water-jacket is of little importance from the economy point of view in the best of existing engines.

The results I have given were obtained with a relatively large gas-engine cylinder, but the tests made on the best gasoline engines now show equally good values. Thus, H. Ricardo has shown that gasoline engines operating at 1600 r.p.m., with overhead valves opening directly into the cylinder which was 7.25 in. in diameter with an 8.50-in. stroke, readily give an indicated thermal efficiency of 33 per cent and this value is about 0.7 of the air standard and about 88 per cent of the actual working-fluid standard. Mr. Ricardo has designed and built a special single-cylinder gasoline engine arranged so as to permit of altering the compression-ratio while the engine is running. He has published in Table 3 the maximum indicated thermal efficiency obtained at values of 1/4, 1/5 and 1/7 respectively for $1/r$. To enable this wide compression range to be attained he used benzol. Mr. Ricardo followed me in giving an approximate formula for the actual working-fluid efficiency at different compression. I proposed the use of a value of 1.285 for γ for the particular working fluid of the gas engine; for the products of combustion of benzol and gasoline Mr. Ricardo uses 1.295.

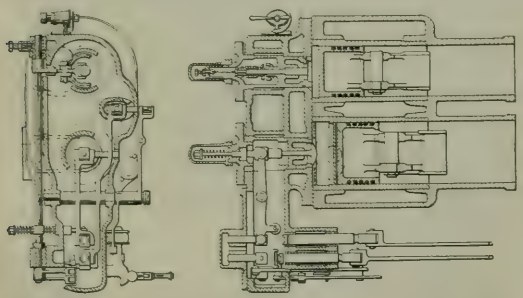

FIG. 3—VIEW OF THE TWO-STROKE ENGINE BUILT BY DUGALD CLERK IN 1886

TABLE 3 — VARYING COMPRESSION-RATIO EXPERIMENTS USING BENZOL

Compression-Ratio	Maximum Indicated Thermal Efficiency Calculated $E=1-(1/r)^{0.296}$	Maximum Indicated Thermal Efficiency Observed	Ratio of Observed to Calculated Thermal Efficiency	Air-Cycle Efficiency	Ratio of Observed Thermal Efficiency to Air-Cycle Efficiency
1/4	0.337	0.277	0.82	0.425	0.650
1/5	0.380	0.316	0.83	0.475	0.665
1/7	0.440	0.372	0.85	0.540	0.685

The change from 1/4 to 1/7 compression-ratio raises the indicated thermal efficiency from 27.7 to 37.2 per cent; that is, only 74.5 per cent of the fuel used at the low compression is required to produce the same power at the higher, and the ratio between no heat loss and practice rises from 82 to 85 per cent. The mechanical efficiency also rises, so that the saving is well worth making. The air-cycle ratio varies from 0.650 to 0.685, practically 0.7, the same as with the gas engine.

If all fuels had properties similar to benzol, it would be possible to get these high efficiencies by simple redesigning, but some fuels "knock" badly under compression-ratios with which others work quietly. This knocking is a great difficulty, which is as yet only partly understood. All we know positively is that high compression-ratios produce knock; why, it is difficult to say.

KNOCKING, PINKING, DETONATING

The knock is a very old enemy. All the early inventors are familiar with it, especially those of us who devoted ourselves to two-stroke engines. I began my work on

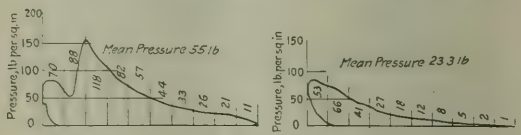

FIG. 4—DIAGRAMS FROM THE PUMP AND ENGINE CYLINDERS OF THE ENGINE SHOWN IN FIG. 3

internal-combustion engines at the end of 1876. I invented, designed and built my first two-stroke engine in 1877, and first exhibited it at work in public at the Kilburn Show of the Royal Agricultural Society in 1879. Fig. 2 is a sectional plan of this engine which had two cylinders, each of 6-in. diameter and 8-in. stroke; one was the pump and the other the engine cylinder. The pump crank followed the engine crank at right angles, and it pumped a mixture of gas and air into an intermediate reservoir through a check-valve. From this reservoir the mixture was supplied to the engine cylinder by a slide-valve. The reservoir pressure was 70 lb. gage. The engine piston moved back to the end of the cylinder, leaving only sufficient mechanical clearance. The exhaust-valve was closed early to cushion the piston. The engine piston moved forward about 2 in. of its stroke, taking in the compressed mixture from the reservoir; the slide-valve cut off the supply and caused ignition by an incandescent platinum cage carried in the slide. The engine gave 4 b.hp. at 300 r.p.m. It knocked bady with

rich mixture; even with weak mixtures of coal gas and air the knock could still be heard.

A larger engine was built with a cylinder 10 in. in diameter and an 18-in. stroke, which knocked so badly that the blow could be felt in the ground outside the building about 100 ft. away, and was heard also at long distances. The knock was overcome by altering the point of ignition, removing it from the admission port. Water spray, too, was injected into the cylinder at full load. A modified engine of this type was built in 1886. A sectional plan view is given in Fig. 3 and Fig. 4 shows diagrams from the two cylinders. This engine knocked less than the other, but could be caused to knock badly by keeping the compression admission-valve open to the engine cylinder too close to the ignition point.

Fig. 5 shows diagrams from the engine and pump cylinders of another type of two-stroke compression engine. Fig. 6 shows an original diagram from engine and pump cylinder. The combustion space was formed between two pistons which balanced each other, and the pistons moved together to perform all the required valve actions. The engine knocked badly under all conditions of running, as is evident from the engine diagram shown in Fig. 6.

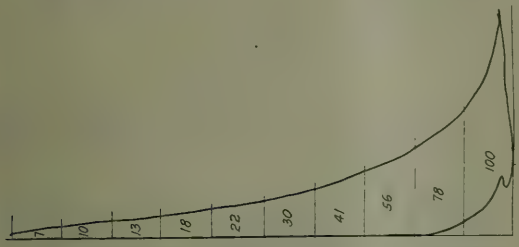

FIG. 5—DIAGRAM FROM THE ENGINE CYLINDER OF A TWO-STROKE COMPRESSION ENGINE

The three types of engine all knocked badly, and at the time it was difficult to understand why. All the engines had one feature in common; the gas mixture was forced into the combustion space and the last portion was injected at high velocity under compression-pressure from the pump through the rapidly closing ports or passage of the charging valve. The mixture was undoubtedly agitated violently at the last moment previous to ignition. Accordingly the pressure-rise was so rapid as to cause great shock. Non-compression engines, such as the Lenoir and the Bischoff, also give a violent knock. Fig. 7 is a sectional elevation of the Bischoff non-compression engine. Air and gas is drawn into the cylinder from the atmosphere and gas supply pipe through an automatic inlet-valve, and ignition is caused by the piston overrunning a small port having a check-valve and sucking in a portion of a flame burning outside. This engine gives a violent shock with a rich mixture. The shock obtained with rich mixtures of coal gas and air in those early days was very violent; there was no doubt about it. Mr. Midgley's graphic description of the sulphuric-ether knock applies accurately to the worst knocking.

> The curve rises smoothly along compression but, shortly after ignition, something happens. This is the knock, the noise of which can be heard across a 10-acre lot

The first engine designed and built by me which was quite free from knock was produced in 1880 at Glasgow and patented in 1881. It is the engine best known by my name, and is used in thousands for small and large

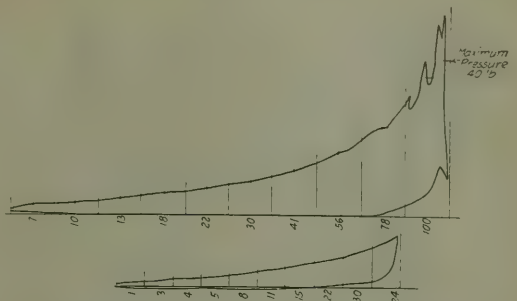

FIG. 6—DIAGRAM FROM A TWO-STROKE ENGINE BUILT IN 1885 SHOWING THE EFFECT OF KNOCK ON THE EXPANSION

power-units. A sectional plan view and elevation are shown in Fig. 8, and the diagram of an engine of 9-in. cylinder diameter and 20-in. stroke is reproduced in Fig. 9. The explosion was perfectly smooth in these engines; no knock was experienced under any circumstances. The ignition, as I now know, was rather slow, because the design of the pump and the engine minimized possible turbulence. Compression-pressures of 60 lb. above atmospheric pressure were considered high in 1881, and at these pressures knock difficulties did not appear. The experiments with compression-ratios as high as 5 to 6 in gas engines and the natural wish to get higher mean effective pressures by using richer mixtures produced conditions in experimental engines of four-stroke type which again produced the knock in a milder form. At the same time the use of gasoline under high compres-

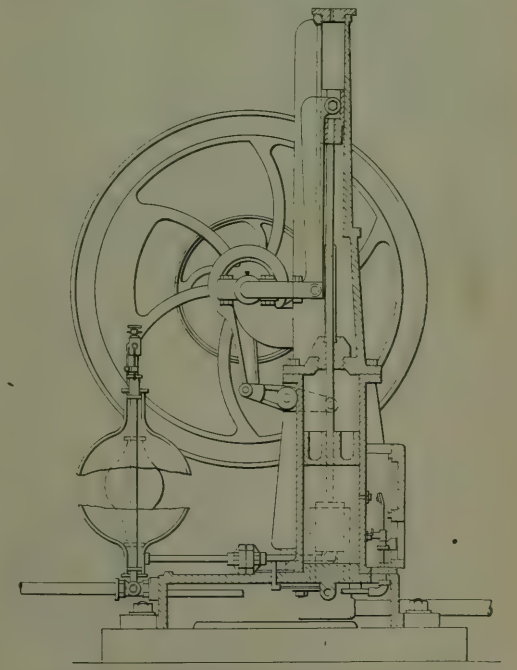

FIG. 7—SECTIONAL ELEVATION OF THE BISCHOFF NON-COMPRESSION ENGINE BUILT IN 1880

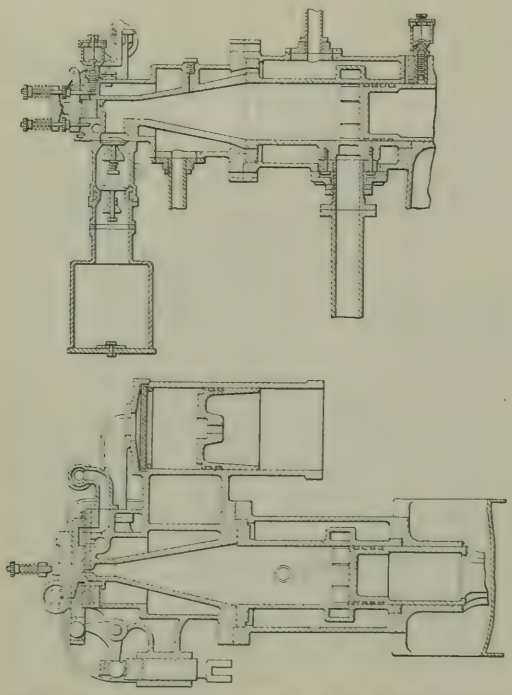

FIG. 8—SECTIONAL ELEVATION (ABOVE) AND PLAN VIEW (BELOW) OF A TWO-STROKE COMPRESSION ENGINE BUILT IN 1881

sions and paraffin or kerosene at lower ratios produced knocking of a very severe type. Water-injection was adopted by some firms to control this in exactly the same way as I had controlled knock in 1880.

AIR AND EXHAUST SUPERCOMPRESSION

I experimented upon four-stroke engines with rich mixtures beginning in 1902, and applied supercompression by added air and also by cooled exhaust-gases. The air supercompression had been tried by Daimler many years before but had not come into use. The exhaust-

FIG. 9—DIAGRAM FROM A 12-HP. ENGINE BUILT IN 1881 HAVING A CYLINDER DIAMETER OF 9 IN. AND A STROKE OF 20 IN.

gas supercompression was originated by me. The idea was to use strong gas and air-charges at high compressions, controlling the flame temperatures, which would then be excessive, by adding cooled exhaust-gases under pressure to the cylinder at the charging end of the stroke. The total pressure of the charge was thus raised by 3 to 5 lb. above that of the atmosphere before the compression began. The total weight of working-fluid per cylinder-charge was thus increased by from 20 to 25 per cent, and so the flame temperature was reduced. At the same time the mean available pressure was increased. The proportion of carbonic acid gas in the exhaust, too, prevented preignition and also knocking. Fig. 10 is an indicator-card showing two superposed diagrams, one without and the other with exhaust supercompression. The sharp peaked diagram with the lower compression is that without exhaust-gas supercompression. The flattened-top diagram with the higher compression has been produced by exhaust supercompression, and its effective area is greater than the other. The ordinary diagram is ap-

FIG. 10—INDICATOR SHOWING TWO SUPERIMPOSED DIAGRAMS, ONE WITH AND THE OTHER WITHOUT EXHAUST SUPERCOMPRESSION

proaching nearly to a knock; the other is beautifully smooth-running. In this experiment the gas-charge is identical for both types, and by moving a lever the engine is made to run on or off supercompression at will. In this experiment a plate was bolted to the end of the piston to increase the compression; the plate was very hot, and although the engine ran steadily, giving 28 b.hp. with exhaust supercompression, it preignited and pulled up when the supercompression charge was cut off, as shown on the diagram which is reproduced in Fig. 11. In this case the preignition was noiseless. Fig. 12 gives particu-

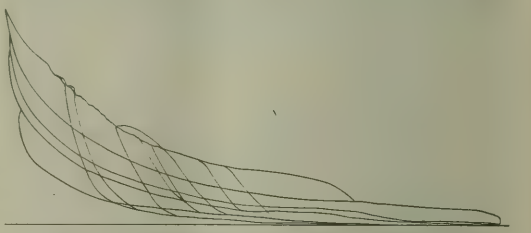

FIG. 11—DIAGRAM SHOWING PREIGNITION WHEN THE EXHAUST WAS SHUT OFF

lars of a test with supercompression and shows an engine diagram, while Fig. 13 is a light-spring diagram which demonstrates the action of the pressure exhaust-gases in filling up the cylinder at the end of its charging stroke.

I have also applied exhaust gases to prevent preignition in large gas engines when using coke-oven gas and to permit the compression-ratio to be increased without

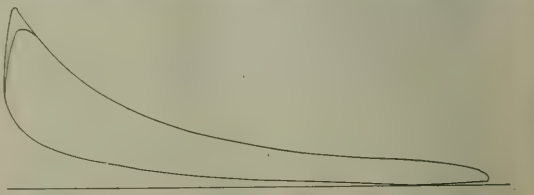

FIG. 12—EXHAUST SUPERCOMPRESSION DIAGRAM WITH THE ENGINE LOADED

knocking. The cylinders, 23 in. in diameter with a 24-in. stroke, were of the vertical tandem type, and a compression-ratio of 1/7 was attained with coke-oven gas, which is rich in hydrogen. At first the exhaust gas was cooled and taken into the engine cylinder with the air-charge; later it was drawn into the gas conduit and mixed with the gas to be supplied to the engine, the same proportion being used as in the first instance. The exhaust gas successfully deals with the use of rich gases in large engines. These vertical engines are built in sizes from 300 to 2000 b.hp. Small parafin or kerosene engines of high speed which knock badly when arranged in the ordinary way become practically silent when their exhaust gases are taken into the engine. In my opinion, you will find that your trouble from knock in kerosene engines will be solved by using a mixture of exhaust from the engine with the air entering the cylinder. I do not know to what compression-ratios you can carry the method.

Residual Turbulence

In the foregoing account of my experience on knocking I have not troubled you with theories but have confined myself to difficulties found in the course of many years' design and experiment. I am, of course, deeply interested in the theory of the working fluid and I am much gratified that American engineers are taking the great interest in abstract matters which is so evident from the many able papers presented before this Society.

I shall now deal with the theory of the working fluid but first I would say that my friend Mr. Wheeler has somewhat mistaken the nature of my discovery of suction turbulence. What I have discovered and proved definitely is, that the turbulence which we all know was created by the high velocity of the air and gas in entering the cylinder, persists during the compression stroke of the gas or gasoline engine to a sufficient extent to affect profoundly the rate of inflammation of the compressed mixture. This investigation was made by me in 1911. Long before that time I was fully aware that (*a*) turbulence existed in the engine cylinder during the admission of the charge through the inlet valve and passage and (*b*) that if turbulence be produced in a mixture of gas and air the inflammation of the charge proceeds more rapidly. With regard to the first point I made the following statement in my book The Gas Engine[8] in 1885 while discussing the question of stratification in the Otto engine cylinder:

> A little consideration of the arrangement of the Otto engine will show that stratification cannot have any existence in it. The end of the combustion space is usually flat, and sometimes the admission port projects slightly into it; the area of the admission port is about 1/30 of the piston area; accordingly the entering gases flow into the cylinder at a velocity 30 times the piston velocity, or at the Otto piston speed, about 120 m.p.h.
>
> Great commotion inevitably occurs; the entering jet projects itself through the gases right up against the piston, and then returns eddying and whirling till it mixes thoroughly with whatever may be in the cylinder. The mixture becomes practically homogeneous even before compression commences
>
> Experiments made by Dr. John Hopkinson and the author on full-size glass models of the Otto cylinder show this mixing action very beautifully

With regard to the second point, I made the following statement in my paper on The Theory of the Gas Engine,[9]

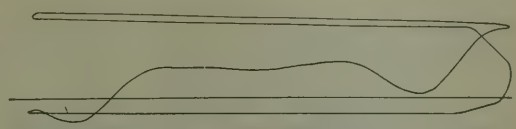

Fig. 13—Indicator Diagram Obtained with a Light Spring Showing the Action of the Pressure Exhaust Gases in Filling Up the Cylinder at the End of the Charging Stroke

read to the Institution of Civil Engineers in London on April 4, 1882:

> The author has found it possible to ignite a whole mass in any given time between the limits of 0.10 and 0.01 sec., by so arranging the plan of ignition that a small volume of gaseous mixture is first ignited, expanding and projecting a flame through a passage into the mass of inflammable mixture, and thus adding to the rate of ignition the mechanical disturbance produced by the entering flame. He has succeeded by this means in producing maximum pressure in 0.01 sec. in a space containing 200 cu. in. This rate of ignition is too rapid, and would not give the engine time to take up the slack in bearings, connecting-rods, etc. But by firing a mixture with varying amounts of mechanical disturbance almost any time of ignition can be obtained between 0.01 and 0.10 sec. It does not matter whether the mixture used is rich or weak in gas; the rich mixture can be fired slowly and the weak one rapidly, just as may be required. The rate of ignition of the strongest possible mixture is so slow that the time of attaining complete inflammation depends on the amount of mechanical disturbance permitted

Then followed diagrams which were taken from an early Otto engine and they were referred to as follows:

> A diagram from an Otto engine shows what happens in a compression engine of type 3 [type 3 was the engine in which heat was added and discharged at constant volume] when the ignition comes late and the movement of the piston overruns the rate of the spread of the flame. It is then seen that the maximum pressure is not attained until far on in the stroke, and as a consequence great loss of power results, the pressure attaining its maximum when it is time for the exhaust-valve to open. This may happen from several causes, a too diluted mixture, or too little mechanical disturbance by the entering flame; or the ignition may be missed until the pressure begins to fall by the forward movement of the piston, when the rate of inflammation begins to come more nearly to Mallard's number of 11 in. per sec. This slow combustion, or rather slow inflammation, is to be avoided in the gas engine. Every effort should be made to secure complete inflammation as soon after ignition as practicable

Notwithstanding my regular use of flame projection to increase mechanical disturbance when ignition was too

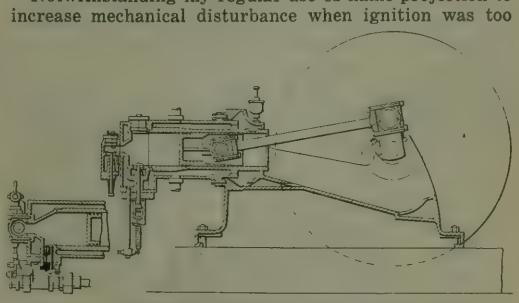

Fig. 14—Longitudinal Sectional Elevation and Partial Sectional Plan of the Gas Engine Used in Turbulence Experiments

[8] See The Gas Engine, pp. 255-6.

[9] See *Proceedings of the Institution of Civil Engineers*, vol. 69, p. 243.

slow, yet I entirely missed the point that residual turbulence remaining in a gas or gasoline-engine cylinder during the completion of the compression stroke was the really efficient accelerator of the spread of the flame which caused the difference between relatively slow flame-propagation in the closed-vessel experiments as compared with the engine cylinder. The experiments demonstrating this interesting point were made by me in 1911 and published in the Report of the Gaseous Explosion Committee of the British Association at its meeting at Dundee in 1912. Fig. 14 shows a longitudinal section and a part sectional plan of the gas engine used in the experiments. The cylinder was 9 in. in diameter and the stroke 17 in. It was the medium engine of the Institution of Civil Engineers Committee tests for air standard already referred to. Fig. 15 reproduces two of the diagrams taken; in the upper the back electric-ignition was used and in the lower the side ignition.

I had long before observed that gas engines would have been impracticable had the rates of explosion been the same in actual engine cylinders as in closed-vessel experiments. In an engine running at 150 r.p.m., the stroke takes 0.2 sec., so that it would be impossible to attain the maximum pressure till the end of the stroke with a time explosion of 0.2 sec. In an ordinary engine working at such a speed, maximum pressure is attained in from 1/20 to 1/30 sec. with a mixture of about 1 part of gas to 9 parts of air and exhaust gas; and no complete explanation of the greater rate was offered till 1911, when, in the course of some experiments, I found that the rate of explosion-rise in the same engine varied with the rate of revolution, increasing with increased number of rotations per minute, and was due to the turbulence or eddying caused by the rush of gases into the cylinder during the suction stroke, which persisted during the compression stroke. I was studying the effect of this suction turbulence on heat loss during the working stroke of a gas engine by drawing in a combustible charge into the cylinder in the ordinary way, and then tripping the valves and compressing and expanding this charge for one or two revolutions before firing. By this means turbulence was given time to die away, and it was expected that a comparison of an expansion-line obtained in this way with that following a normal ignition would show the effect of suction turbulence on heat loss. The experiments did not clearly indicate increased heat loss on the explosion and expansion-line, probably because of the relatively high radiation and convection losses at the particular temperatures used, but another interesting point was discovered which is of considerable importance in the practice of the internal-combustion engine in all its forms. It was at once found that the effect of damping-down turbulence was to retard the rate of inflammation or explosion to a remarkable extent, so that the nature of the indicator-diagrams was completely changed. Two of the diagrams so taken are reproduced in Fig. 15, from which it will be seen that suction turbulence is of vital importance in producing the high rate of inflammation necessary to secure economical working in all internal-combustion engines. In Fig. 15 the ordinary ignition a to b at the end of the first compression-stroke rises to maximum temperature of explosion in 0.037 and 0.033 sec. respectively; while the ignition a' to b' on the third compression of the piston, after the imflammable mixture has been compressed and expanded twice and then again compressed, takes respectively 0.092 and 0.078 sec. The mixture in both cases was 1 volume of gas and 9.3 volumes of air and other gases. The cylinder was kept hot, the jacket temperature being 70 deg. cent. (158 deg. fahr.), and the engine was run at 180 r.p.m. under full-load conditions. The engine had a 9-in. cylinder diameter and a 17-in. stroke. It was fitted with two electric igniters, as shown in Fig. 14, one operated in the charge inlet port at the back of the combustion-chamber, and the other at the side of the cylinder, close to the piston when it was at its full-in position. In the upper diagram of Fig. 15 the back electrical-igniter was used for both ignitions on the diagram, and in the lower the ignition was effected by the side igniter. It will be observed that the inflammation is more rapid in both normal and delayed ignition with the side igniter, but in both cases the time of inflammation without turbulence is about two and one-half times that of a normal ignition when the gases have some turbulent motion. In most gas and gasoline engines the mean velocity of charge-flow through the inlet-valve is at the rate of 100 ft. per sec., and flame carried at this rate would completely fill the combustion space of this engine in about 1/130 sec., as the distance from each igniter to the extreme wall-limit is about 9 in. The actual time taken for normal complete inflammation was respectively 1/27 and 1/30 sec., so that the rate of normal flame-propagation with turbulence was about $100 \div 4.5 = 22.25$ ft. per sec., while the rate with trapped ignition and turbulence nearly-died-down was about 8.9 ft. per sec. From this it appears that the effect of suction turbulence is to increase the rate of inflammation about 13 ft. per sec. in this particular engine running at 180 r.p.m. The rate of inflammation in Clerk's closed-vessel experiments with a similar mixture was about 4 ft. per sec., and in Bairstow and Alexander's corresponding experiments 2.5 ft. per sec. In a large vessel having a capacity of 6.2 cu. ft., with a similar mixture, Hopkinson found the rate of inflammation about 5 ft. per sec. The velocity of inflammation in an actual engine is thus from four to five times that found in a closed vessel by Clerk and Hopkinson, and nine times that found by Bairstow and Alexander. My experiments would suggest a residual turbulence-effect in this engine at the moment of explosion of about 20 ft. per sec.

The late Professor Hopkinson experimented on turbulence at the same time as myself, but he operated in a closed vessel and produced his turbulence by the rotation of a fan within the mixture. Hopkinson's apparatus consisted of a cylindrical vessel 12 in. in diameter and 12 in. long, which was lined with strip copper to measure the rate of heat loss by the increased electrical resistance of this strip. A small fan was mounted in the center of the vessel, and comparisons were made of the results of exploding the same mixture, with the fan at rest and in motion. The experiments showed a great increase of the speed of inflammation consequent on the motion of the gas. With a mixture of 1 part of gas and 9 parts of air by volume, the time from ignition to maximum pressure with the gas at rest was about 0.13 sec.; with the fan running at 2000 r.p.m. it was reduced to 0.03 sec., and at 4500 r.p.m. to 0.02 sec.

Hopkinson also arranged experiments to determine the turbulence in an engine of 7-in. cylinder diameter and 15-in. stroke, running at 240 r.p.m. and driven by an electric motor. The method used was to determine the rate of loss of heat from a platinum wire mounted in the combustion-chamber, the wire being heated by an electric current. Hopkinson states that within moderate limits of temperature the heat loss from such a wire is proportional to the temperature-difference between it and the surrounding gas. The ratio between heat-loss and

temperature-difference is a measure of the effective conductivity of the gas, and depends on its temperature, density and state of motion. If the first two factors are the same, the effective conductivity depends only on the state of motion, and can be taken as a measure of its amount. Measurements were made of effective conductivity at the top of compression, first with the valves working in the ordinary way and then with the valves closed so that the same charge of air was continually compressed and expanded and suction turbulence was absent. At 240 r.p.m. the conductivity of the compressed air was more than 60 per cent greater in the first case than in the second, and at 60 r.p.m. the difference was only about 20 per cent. The temperature and density of the gas were the same in both cases, so that the difference could be due only to motion.

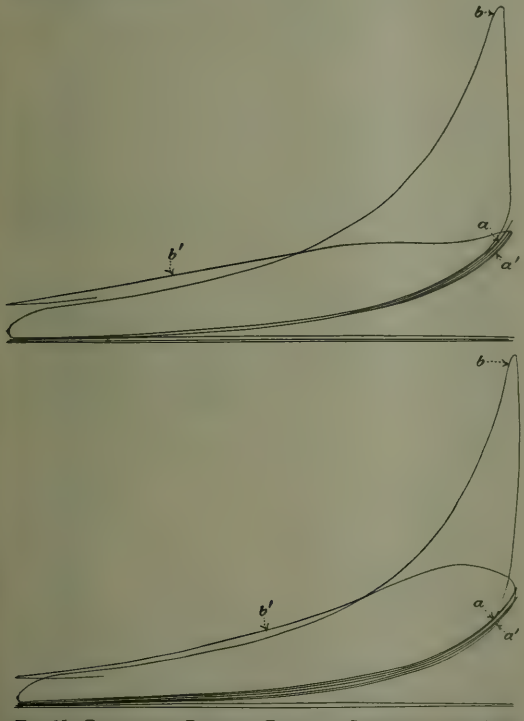

FIG. 15—TWO OF THE DIAGRAMS TAKEN IN CONNECTION WITH THE TURBULENCE EXPERIMENTS.
In the Upper the Back Electric Ignition was Used and in the Lower the Side Ignition

Hopkinson mounted a wire before a fan, and determined the air velocity which would produce a similar cooling effect on the wire, and from this experiment estimated the residual turbulence at the end of the ordinary compression-stroke.

It is to be remembered that the time of inflammation necessary for a motor-car gasoline engine is very much less than the 1/30 sec. which a gas engine requires. In gasoline engines running at 1200 r.p.m. the time of explosion should be about 1/120 sec., but at 2400 revolutions 1/240 sec. is necessary for efficiency. Dr. Watson

[10] The Explosion of Homogeneous Gaseous Mixtures, published in the *Proceedings of the Institution of Civil Engineers*, vol. 85, p. 1.

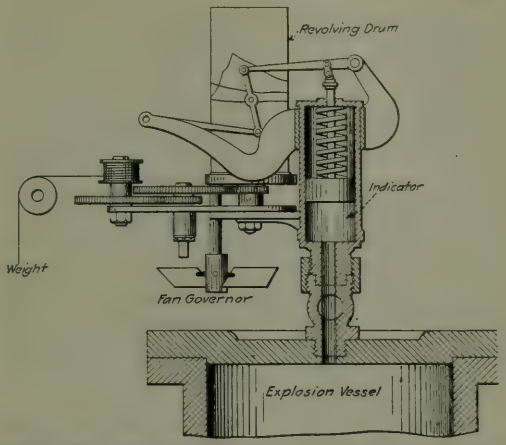

FIG. 16—EXPLOSION APPARATUS USED BY SIR DUGALD CLERK IN HIS EXPERIMENTAL STUDY OF GASEOUS EXPLOSIONS

gives 1/300 sec. as the time in a small gasoline engine. If the flame travels 4 in. to fill this small cylinder, its rate must be 100 ft. per sec., so that a high suction-velocity is necessary to ignite the contents in time to produce an effective stroke. From this it will be seen that the conditions of explosion are very different in closed vessels and actual engine experiments.

GASEOUS EXPLOSIONS

Before considering the other actions in the gas and gasoline-engine cylinder it is necessary to study the general and particular nature of gaseous explosions. I began my experimental study of gaseous explosions in 1884 and read my first paper[10] on the subject before the Institution of Civil Engineers in 1886. The apparatus used by me is shown in Fig. 16 and diagrams from mixtures of air with Glasgow coal-gas and Oldham coal-gas are reproduced in Fig. 17. Of these the most rapid rise to maximum pressure, 0.01 sec., is given by 2 volumes of hydrogen and 5 volumes of air. The most rapid rise with coal gas is 0.05 sec. with Glasgow gas but the time of the mixture commonly used containing 1/10 coal gas with both Glasgow and Oldham gases was 0.13 and 0.08 sec. respectively. In all cases mixtures at rest were used; turbulence was absent.

As a result of these experiments I came to the conclusion among other things that in some cases the whole explosion vessel was completely filled with flame before the maximum pressure was attained and that combustion

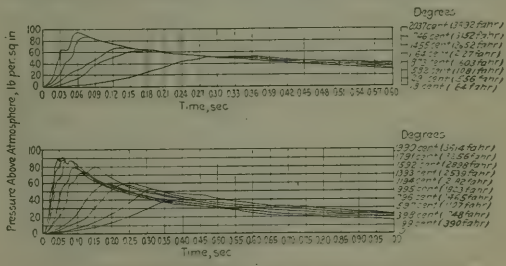

FIG. 17—TWO DIAGRAMS OBTAINED FROM MIXTURES OF AIR AND COAL GAS

continued for a considerable period after maximum pressure. I considered that the detonation of Berthelot which produced a speed of communication of chemical action in hydrogen and oxygen mixtures corresponding to 2 volumes of hydrogen and 1 volume of oxygen, of over 2000 meters per sec. (1.24 miles per sec.) did not exist in hydrogen or coal gas and air mixtures, although something approximating Berthelot's explosive-wave at a much lower velocity can be attained by the use of "a long and powerful spark" or by injecting a large flame from a small separate chamber. The maximum pressure of the explosion is, however, strictly limited and even detonation does not materially increase the maximum pressure. In this the gaseous explosion differs completely from the solid or liquid explosive. Detonation in gun-cotton or trinitrotoluol causes an almost indefinite pressure-increase. Thus Professor Hopkinson proved the pressure of detonating gun-cotton to rise as high as 100 tons per sq. in. No such change of pressure can occur with gaseous explosions; detonation but little exceeds the limit of ordinary inflammation.

It is easy, however, to arrange a gaseous explosion in such manner that the spread of the flame will compress in front of it by its movement a portion of the mixed charge through a check-valve or aperture so that a chamber is filled with mixture compressed above atmospheric pressure by the progress of the combustion. Thus it is easy to obtain explosion-pressures of 200 lb. per sq. in. above that of the atmosphere in a separate chamber instead of only 100 as in an ordinary gaseous explosion at atmosphere. I discovered this fact in 1891 and based on it the flame-starter for gas engines shown in Figs. 18 and 19. Fig. 18 is a diagrammatic section illustrating its action in which *a* is the gas-engine cylinder, *b* a check-valve opening into the exhaust-port, *d* and *c* a chamber connected by pipe *d* with the valve *b*, and *e* is an igniting-valve and *f* a port leading to a charging-pump. The object of the device is to fill the combustion space of the engine with a compressed mixture of gas and air, and then to explode the compressed mixture, thus starting the engine by a high-pressure explosion. To start, the crank is placed off the center; the pump is operated by hand to fill the chamber *c*, pipe *d*, and cylinder *a* with the gas and air mixture at atmospheric pressure, so that no resistance is experienced in operating the pump. The igniter *e* is then operated, and the mixture in the chamber *c* ignites near *e*; the flame, as it spreads through the chamber, forces the unburned mixture before it into the pipe *d*, through the valve *b* into the cylinder *a;* so that when the flame arrives at the valve *b*, it has swept before it into the cylinder all the unburned mixture. When the flame passes the valve *b* it ignites the compressed mixture in the cylinder; and, by producing a high-pressure explosion, the engine is started off with an ample margin of power to overcome the friction of belting and shafting.

In conjunction with F. W. Lanchester, I introduced the starting-gear reproduced in Fig. 19 which was known as the Clerk-Lanchester starter. In this arrangement a Lanchester igniting-valve *g* is used, and the pump for charging the chamber *h* is dispensed with. When the engine is stopping, the valve *i* is opened and air is thus pulled through the chamber *h* by way of the valve *g* at every suction-stroke. The chamber *h*, pipe *j* and cylinder *k* thus became filled with pure air at atmospheric pressure. When the engine is to be started, the gas-cock *l* is opened and gas flows from the main at *m* into the chamber *h* and at *n* into the pipe *j*, a cock on the cylinder is opened to allow flow into the cylinder or the exhaust-valve is held slightly open; the flame *o* burns across the valve *g*, and after a few seconds the mixture of gas and air escapes through *g* and burns in the air. The cock *l* is then closed and the flame shoots back past the valve *g*, and so ignites the mixture within *h*, thus closing the valve *g*. The flame proceeds along *h* and *j* into the cylinder *k*, firing the mixture it has compressed, and the engine is started by a compression explosion. Fig. 20 is a starting diagram obtained from this arrangement. From this it will be observed that a maximum pressure of over 200 lb. per sq. in., as well as a mean pressure of 74 lb. per sq. in., is easily attained as a starting explosion. These flame-starters were largely used for starting gas engines for several years. The principle is interesting as bearing on the theory of the rise of pressure in gaseous explosions, and in 1891 I pictured an ordinary gaseous explosion in an engine cylinder as a flame progressing through the mixture at a moderate rate with a fairly well defined flame-front, the flame compressing the unburned mixture adiabatically until ultimately it fills the whole vessel.

Flame Propagation and Recompression

The late Professor Hopkinson investigated this flame action in a large closed vessel of 6.2-cu. ft. capacity, 23.4 in. internal diameter and 28.75 in. long. The electric-spark ignition was central and a continuous record was taken of the variation in the resistance of fine platinum wires immersed in the gas, at different points; and at the same time and on the same revolving drum the pressure was recorded.

The experiments were made at the engineering laboratory of the University of Cambridge and Cambridge coal-gas was used. This gas had a calorific value at 760 mm. (29.92 in.) pressure and 0 deg. cent. (32 deg. fahr.) of 680 B.t.u. per cu. ft. and 1 cu. ft. required 5.76 cu. ft. of air for complete combustion. The analysis of the gas is given in Table 4, all values being in percentages by volume.

TABLE 4—ANALYSIS OF CAMBRIDGE COAL-GAS

Constituents	Percentage by Volume
Hydrogen	47.20
Methane	35.20
Heavy Hydrocarbons	4.80
Carbon Monoxide	7.15
Nitrogen	5.40
Other Gases	0.25

With 9 volumes of air to 1 of gas fired at atmospheric pressure a maximum pressure of 82 lb. per sq. in. above atmosphere was attained in about 0.25 sec. after firing, and it was found from the readings of the platinum-resistance thermometers that the flame spread roughly at the rate of 59 in. per sec. The spread of the flame differs slightly in different directions.

The flame reached the side-walls of the cylindrical vessel when the pressure was from 15 to 20 lb. per sq. in. above that of the atmosphere. At this point, however, only a small portion of the walls was in contact with the flame, that is the part nearest to the spark, and most of the gas mixture was still unignited. As the flame spread a greater and greater area of the walls came into contact with it, until it completely filled the vessel and was losing heat to every part of it. At this point the pressure had not attained its maximum, being about 70 lb. per sq. in., while the maximum reached was 82 lb. The maximum pressure was attained in less than 1/30 sec. after the flame completely filled the vessel.

The platinum thermometer at the center of the vessel shows that the temperature rises very rapidly after the moment of ignition, reaching 1225 deg. cent. (2237 deg. fahr.) in probably less than 1/50 sec., but that the thermometer rises very slowly until very near the point of maximum pressure. The platinum wire then suddenly melts, from which Professor Hopkinson deduced the temperature of the surrounding gases as 1900 deg. cent. (3452 deg. fahr.). This is the highest temperature attained by the explosion; all other points in the vessel are lower.

The distribution of temperature within this large vessel at the moment of maximum temperature is roughly as given in Table 5.

TABLE 5—DISTRIBUTION OF TEMPERATURE AT THE INSTANT OF MAXIMUM TEMPERATURE

Location	deg. cent.	deg. fahr.
Mean Temperature Inferred from Pressure	1,600	2,912
Center of Vessel	1,900	3,452
Point 4 In. from End Wall	1,700	3,092
Point 0.4 In. from End Wall	1,100 to 1,300	2,012 to 2,372
Point 0.4 In. from End Wall at Side	850	1,562

Professor Hopkinson's view was that at this moment little heat had been lost at the first three points and that the difference in temperature is almost wholly due to the

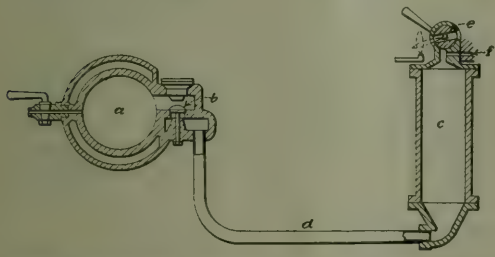

FIG. 18—DIAGRAMMATIC SECTION OF THE CLERK FLAME-PRESSURE STARTER

different treatment of the gas at the different places. At the center of the vessel it has been burnt at nearly atmospheric pressure and compressed after burning to about six and one-half atmospheres absolute, while at next to the last point in the table it has first been compressed to about six and one-half atmospheres as in a gas engine and then ignited with practically no subsequent compression. At the last point much heat has been lost since this is the first point reached by the flame; the gas here is ignited when the pressure is about two atmospheres, its temperature rises instantly to 1300 deg. cent. (2372 deg. fahr.) and at once begins to fall.

In these interesting and important experiments Professor Hopkinson demonstrated that when the vessel was completely filled the mean temperature had reached only 85 per cent of the maximum and that combustion was still proceeding although the whole cylinder was filled with flame. In my 1885 explosion experiments I had inferred this from the nature of the rising line due to spread of flame, but to Hopkinson belongs the great credit of proving experimentally by a platinum thermometer that this was the fact in the large vessel. Hopkinson discovered also the fact that the point of ignition is the

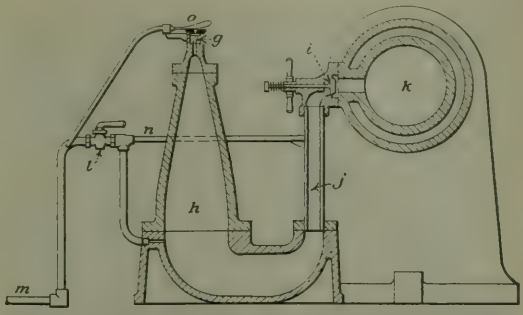

FIG. 19—DIAGRAMMATIC SECTION OF THE CLERK-LANCHESTER STARTER

point of highest temperature in a gaseous explosion and would be still the highest point even if no heat were lost to the walls. Had Hopkinson's vessel been truly spherical, then it would probably have been simpler in its temperature distribution at maximum temperature, as approximately every part of the wall would have been reached by flame from the center ignition at the same instant. Then we could consider the expanding sphere of flame to increase its radius at the rate of 59 in. per sec. and compress the gas and the air before it toward the walls. At first the gas and air mixture would be compressed adiabatically by the flame, just as occurs in my flame-starter already explained. After a certain progression the compressed gases at the walls in the act of igniting would move toward the center of the sphere, as well as to the walls, and so the flame at the central part would be recompressed adiabatically and the flame temperature would rise because of the work done upon it. The suction turbulence in the engine cylinder will no doubt modify this action but broadly the igniting point or points will always reach the highest temperature in the cylinder.

THE SPECIFIC HEAT OF FLAME

My later experiments on gaseous explosions on a new apparatus in the year 1900 and the experiments of many able and ingenious men in America and England following along similar lines proved among other things that the whole heat of combustion is not evolved at the maximum temperature and that either specific heat increases very considerably with the temperature or combustion is suppressed by some limiting cause such as dissociation, or combustion is continued after spread of the flame to a very great extent, or some other cause of heat loss exists than convection. To study the phenomena of heat

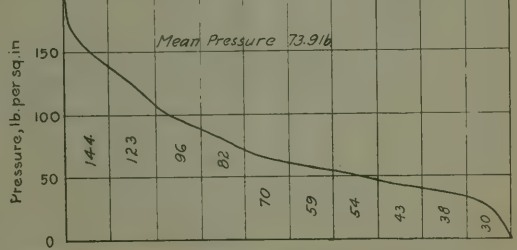

FIG. 20—DIAGRAM OBTAINED FROM THE CLERK FLAME-PRESSURE STARTER

loss and variation of specific heat I devised a new method of experiment in 1904 to which I have already referred. By it the actual working fluid behind the piston could be made to give information on these points during the progress of explosion, combustion and expansion in a working gas engine. The problem is a difficult one, and so far as my knowledge carries me, no previous attempt had been made even to determine a cooling curve for flame gases behind a moving piston.

The engine selected for the first experiments had a cylinder 14 in. in diameter with a 22-in. stroke; the exhaust and inlet-valve levers were supplied with longer pins than usual, so that the rollers mounted on these pins could be moved into or out of the range of the exhaust and inlet-valve cams. When each roller was caused to slide to one end of its pin, the cam passed clear of it and the lever was not operated. When at the other end of the pin the roller engaged with the cam and the lever operated in the usual way. A spring-and-trigger gear was arranged so that the rollers could be put out of range of the cams at any required instant. By this contrivance the engine could be run in its normal way in accordance with the Otto cycle at either light or heavy load, and any given explosion could be selected for the purpose of the experiment by operating the trigger at the proper moment. It was thus possible to run the engine at its normal speed under the usual propelling explosions, and to select at any given moment any particular charge, move the rollers out of the range of the cams immediately the charge entered, and so obtain an explosion and expansion stroke in the usual manner, with the usual charge. But both inlet and exhaust-valves were held closed and the charge retained in the cylinder. When the exhaust period was approached, the exhaust-valve remained shut, and accordingly the hot exhaust-gases were retained in the cylinder and compressed by the return stroke of the piston into the combustion space at the end of the cylinder. The energy of the flywheel was sufficient to keep up the rotations of the engine, with but little fall in speed during the short period of observation. The piston was thus caused to move to and fro, alternately compressing and expanding the hot gases which were contained in the cylinder so long as the gear prevented the operation of the inlet and exhaust-valves.

An indicator-card taken from such an initial explosion and expansion and the subsequent series of compressions and expansions is given at Fig. 21; *a b* is the ordinary compression-line indicating the compression of the charge before explosion, *b c* is the usual explosion-line, and *c d* the usual expansion-line after explosion. At *d*, however, instead of the pressure falling to atmospheric by the opening of the exhaust-valve, as the exhaust-valve remains closed no escape of the hot products of combustion is possible, and accordingly the return of the piston produces the compression-line *d e;* the next outward movement of the piston produces the expansion-line *e f*, followed by the compression-line *f g;* expansion-line *g h;* compression-line *h i;* expansion-line *i j;* compression-line *j k;* expansion-line *k l*, and so on. In this diagram the successive compression and expansion-lines have continued to be traced until the fall of pressure due to cooling brings the contents of the cylinder at the outer end of the stroke below atmospheric pressure, when the outer atmosphere opens the valves against the pressure of their springs, and so the experiment terminates. It will be observed that cooling is proceeding during the tracing of all these lines; had no cooling occurred on any particular expansion and compression stroke, the compression-line would lie on top of the expansion-line. Consider, for example, the moment represented by the point *e* when the piston is at the extreme inner end of its stroke; then the combustion space is filled with hot gases at a temperature and pressure corresponding to the point *e;* after a complete expansion and compression, a complete revolution of the crank, the piston is again at its innermost position, and the whole of the gases are again contained in the combustion-chamber at a pressure and temperature marked by the point *g*. This point *g* is lower than *e* and, as the weight of the gaseous contents has not changed, it follows that the temperature at *g* is lower than at *e*. The points *e, g, i, k* and *m* thus indicate the temperatures of the gases at the same volume at intervals of one revolution of the engine.

If the engine be running at 120 r.p.m., the temperatures represented by the points *g, i, k* and *m* give the successive temperature-falls suffered by the contents during successive revolutions, each lasting 0.5 sec. In the same way the successive temperatures of the gaseous contents at the outer ends of the stroke are given by the pressures at *d, f, h, j* and *l*. Call the successive temperatures at the outer end corresponding to these points t_1, t_3, t_5, t_7 and t_9 and the temperatures at the inner end of the stroke t_2, t_4, t_6, t_8 and t_{10}, corresponding to the points *e, g, i, k* and *m*. These temperature changes are partly due to heat-loss from the gases to the cylinder walls and partly due to work done on the piston by the gases or by the piston on the gases. The points at both ends of the stroke when properly dealt with give curves of temperature-fall due to heat-loss to walls.

Fig. 22 shows a compression and expansion diagram without the explosion-line. Consider first the series of points at the inner end of the stroke; obviously, if no cooling took place in the cylinder there would be no fall of temperature such as is shown between *e* and *g*. This drop is not entirely due to cooling, as will be seen when we consider what happens to the gases between the points *e* and *g*. When the engine piston expands the gases from *e* to *f* and compresses from *f* to *g*, a portion of the total heat has passed through the cylinder walls, but some work has also been done by the gases upon the piston. When the expansion *e f* takes place, the gases perform work on the piston equal to the area *e f o p;* when the compression *f g* takes place, the piston performs work on the gases equal to the area *f g p o*, so that more work has been performed by the gases on the piston than by the piston on the gases. Some work has therefore been done by the gases in the processes intervening between the points *e* and *g;* that is, part of the temperature-difference t_2-t_4 is due to work done; it is not all due to heat lost through the cylinder walls. The difference between the two work-areas is *e f g*, so that the temperature-fall t_2-t_4 is due partly to heat loss to walls and partly to work done by the gas.

If the specific heat of the gaseous mixture at the temperatures between t_2 and t_4 be known, then the temperature-fall due to the work-area *e f g* can be calculated, and when deducted from the total temperature-fall it gives the temperature-fall due to heat-flow through the cylinder walls. It is found that the specific-heat value need be only approximately known, as the temperature-fall equivalent of the work-area *e f g* is small in comparison with the total temperature-fall and little error is introduced by a considerable error in the specific-heat value. This method enables a true temperature-fall curve to be drawn, showing the progressive fall of temperature incurred from revolution to revolution under the actual

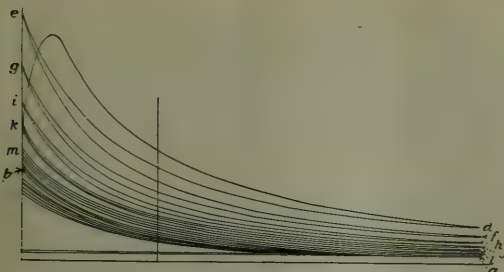

FIG. 21—DIAGRAM OF THE EXPLOSION AND ALTERNATE COMPRESSION AND EXPANSION OF HOT GASES IN AN INTERNAL-COMBUSTION ENGINE CYLINDER

working conditions of the engine. Proceeding in this way I have determined the cooling curve for the engine referred to; it is an Otto-cycle gas engine of 60 b.hp. built by the National Gas Engine Co., Ltd., of Ashton-under-Lyne. The experiments were made with Ashton coal-gas at the Company's works, Ashton.

Fig. 23 shows an indicator-diagram taken by my method from this gas engine, which had a bore of 14 in. and a 22-in. stroke, when working under a brake load of 50 hp. at 160 r.p.m. with the water-jacket at a temperature of about 71 deg. cent. (160 deg. fahr.). A Richards-Casartelli indicator was used. The temperature of the charge before compression was calculated at 95 deg cent. (203 deg. fahr.).

Proceeding in the manner described, I have prepared cooling curves from the engine under two conditions (*a*) with no load and the cylinder kept cool, and the engine running at 120 r.p.m., and (*b*) with full load and the jacket-water at 71 deg. cent. (160 deg. fahr.) and the engine running at 160 r.p.m. The cooling curves show the temperature-fall due to heat-loss, with mean tem-

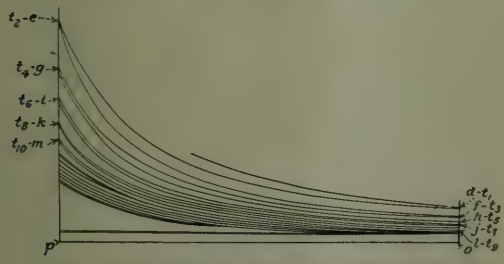

FIG. 22—A COMPRESSION AND EXPANSION DIAGRAM WITH THE EXPLOSION LINE OMITTED

peratures of the gases varying from 100 to 1500 deg. cent. (212 to 2732 deg. fahr.), and the exposure calculated to 1 sec. The curves show the rates of temperature-fall found under these conditions for complete strokes and partial strokes of three-tenths of the whole at the compression end. Fig. 24 gives the temperature-falls incurred per second for different mean-temperatures calculated in time.

Consider first the curves *a a'*. These correspond to the conditions in the engine cylinder when the engine is running at 120 r.p.m. without any load, so that very few ignitions keep it in motion, and while the water-jacket is kept cold by running water at 13 deg. cent. (55 deg. fahr.) freely through it. Under these conditions the end of the piston and the interior surface of the valves will be but little heated by the explosions, and the interior surfaces of the cylinder and combustion-space wall will tend to fall between the explosions to the water-jacket temperature of 13 deg. cent. (55 deg. fahr.).

The curve *a* is that for the complete stroke, while *a'* is for the partial first three-tenths of the stroke. Taking *a* first, it appears that the rate of temperature-fall per second for a mean temperature of 1300 deg. cent. (2372 deg. fahr.) is 1460 deg. cent. (2660 deg. fahr.); that is, that a complete stroke of the engine during which the mean temperature in the cylinder was 1300 deg. cent. (2372 deg. fahr.) would lose heat to the walls at a rate sufficient to produce a temperature-fall of 1460 deg. cent. (2660 deg. fahr.) per sec. The stroke in this case does not last a full second, but only ¼ sec., so that the real temperature-fall under these conditions would be

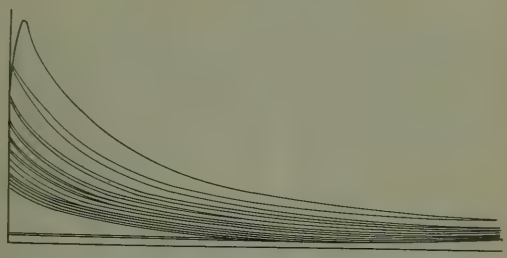

FIG. 23—INDICATOR DIAGRAM OBTAINED FROM A GAS ENGINE HAVING A CYLINDER 14 IN. IN DIAMETER AND A STROKE OF 22 IN.

1460 ÷ 4 = 365 deg. cent. (689 deg. fahr.). It is better, however, to express the temperature-fall in degrees per second.

The curve *a*, when prolonged to the zero of temperature-fall, cuts it at the temperature of 65 deg. cent. (149 deg. fahr.), which means that when the gases within the cylinder fall to the mean temperature of 65 deg. cent. (149 deg. fahr.), no further heat-loss occurs to the enclosing walls; that is, the mean temperature of the enclosing walls for the complete stroke of the engine must be 65 deg. cent. (149 deg. fahr.). The water outside does not succeed in keeping down the mean temperature

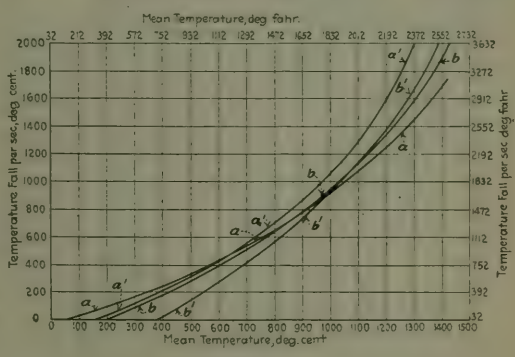

FIG. 24—FALL IN TEMPERATURE PER SECOND FOR DIFFERENT MEAN TEMPERATURES

of the interior surface, including valve surfaces and piston-end, to its own temperature of 13 deg. cent. (55 deg. fahr.). This curve thus gives an interesting indication of the mean temperature of the walls.

Taking curve a' in the same way, its general slope is greater than a, and it cuts the zero line at 165 deg. cent. (329 deg. fahr.), and crosses the curve a at a mean temperature of 610 deg. cent. (1130 deg. fahr.). Up to this point the temperature-fall is less than that of a for a given mean-temperature; above it the temperature-fall rapidly increases with increasing mean-temperature, so that the rate of fall is considerably greater in a' than in a at the mean temperature of 1300 deg. cent. (2372 deg. fahr.).

The fact that the intersection with the zero line is at 165 deg. cent. (329 deg. fahr.) indicates that the mean temperature of the cylinder walls is much higher for the inner three-tenths of the stroke than for the whole stroke. This was to be expected, because the proportion of piston-end, valve surface and other unjacketed surfaces becomes greater as the piston moves in; that is, the water-jacketed cylinder surface is covered as the piston moves in, so that the ratio changes, and therefore the mean temperature rises. Apart from this, however, it was to be expected that the surface temperature of the jacketed and unjacketed parts would be highest at the combustion-chamber end, where it is exposed to the maximum temperature. This curve, then, indicates that the mean temperature of the three-tenths surface during the three-tenths period is 165 deg. cent. (329 deg. fahr.), while the mean temperature of the whole cylinder surface during the whole stroke-period is only 65 deg. cent. (149 deg. fahr.) and this with the water in the water-jacket at 13 deg. cent. (55 deg. fahr.).

Comparing now the two curves, a a', at the mean temperatures 1300, 1200, 1100, 1000 and 900 deg. cent. (2372, 2192, 2012, 1832 and 1652 deg. fahr.), it is found that the rate of loss of temperature is less in curve a than in a' by the following percentages, calculated on the a values for the successive temperatures; nearly 26.0, 20.5, 16.0, 13.0 and 10.0 per cent. This clearly shows that, notwithstanding the diminutions of surface exposed in a given time at three-tenths stroke, as compared with whole stroke, the absolute temperature-fall rate is increased. This is probably due to the fact that the mean surface exposed diminishes more slowly than the mean density increases, so that the economical effect of increased density is not realized. Also, the existence of some turbulent motion may mask the other effects. This clearly shows that it is necessary to determine cooling in the cylinder with the moving piston, as the conditions are too little known to be predicted from explosions in closed vessels of fixed capacity. This becomes even more evident when the curves b b' are studied. These curves are taken while the engine is running at a load of 50 b.hp. Here the explosions are almost consecutive, and the water-jacket temperature is 80 deg. cent. (176 deg. fahr.), so that the interior surfaces, both jacketed and unjacketed, are much hotter than in curve a a'; as before, curve b is for whole stroke and b' for first three-tenths of stroke. Curve b cuts the zero line at 190 deg. cent. (374 deg. fahr.), indicating the mean temperature of the enclosing walls during the whole stroke. The condition of the internal surfaces is different, 190 deg. cent. (374 deg. fahr.) as compared with 65 deg. cent. (149 deg. fahr.), a very large increase in temperature. Curve b' cuts the zero line at 400 deg. cent. (752 deg. fahr.), also a much higher temperature. The continued explosion and the hot water-jacket have produced a very considerable change upon the surface temperature of the enclosing walls. Here also the curve b for the whole stroke is less steep than b' for the three-tenths stroke, but, owing to the high wall-mean-temperature at three-tenths, the curves do not intersect till the temperature of 1100 deg. cent. (2012 deg. fahr.) is reached. Below this figure the temperature-fall is less in b'; above that temperature it is greater.

Comparing b b' as a a' have already been treated at the same mean temperatures, it will be seen that for 1300 and 1200 deg. cent. (2372 and 2192 deg. fahr.) the temperature-fall is greater in b' than in b, but only 4 and 2 per cent respectively, calculated on b'; at 1100 deg. cent. (2012 deg. fahr.) the temperature-fall is practically equal; at 1000 deg. cent. (2012 deg. fahr.) b' is less by about 3 per cent on b', and at 900 deg. cent. (1652 deg. fahr.) is nearly 7 per cent less, also calculated on the value of b'. It is thus seen that for the practically interesting range of mean temperatures, 1300 to 900 deg. cent. (2372 to 1652 deg. fahr.) the temperature-fall given by the two curves varies but little, and this is due to the higher average temperature of the interior surface in the first three-tenths of the stroke. The point of intersection of the curves b b' is raised to such a high value that the actual heat-loss at about these temperatures remains nearly constant, although the two curves are undoubtedly different in slope. Now compare the curves a' b', and it will be seen that they are fairly parallel one to the other. Their general slope is very similar, so that, except at the lower end, they could almost be superimposed. It appears that the difference in absolute value of the temperature-fall for the given mean-temperatures was due mainly to the difference between the enclosing wall temperatures.

These experiments prove conclusively that cooling behind a moving piston depends largely on the varying temperature of the water-jacket, and still more on the varying mean-temperatures of the cylinder walls according to the condition of load and water-circulation. Although general laws may be deduced from closed-vessel experiments of fixed volume at varying initial pressures, yet the problem in the working engine is so complex that it is desirable to make many direct determinations on actual engines as to explosion and cooling in cylinders of varying dimensions before endeavoring to deduce any general formulas.

From the curves given in Fig. 24 and specific-heat values of the gaseous contents of the cylinder, heat-losses can be calculated on the explosion-expansion line independently of any knowledge as to the completeness of combustion at any point, and for this purpose I have determined the specific heat of the gases in the following manner: If a gas be compressed without gain or loss of heat from volume V_0 to V_1, and the temperature rises from T_0 to T_1, the mean specific heat of the gas per unit volume at 0 deg. cent. (32 deg. fahr.) and a pressure of 760 mm. (29.92 in.) of mercury at constant volume between the two temperatures is

$$C_v = W \div [\Psi_0 (T_1 - T_0)]$$

where

C_v = the mean specific heat
W = the work done upon the gas
Ψ_0 = a constant depending upon the quantity of gas in the cylinder

This is also true of expansion as well as compression. The dynamical value of the rise or fall of 1 deg. cent.

(1.8 deg. fahr.) for 1 cu. ft. of the gas will be given by the formula:

$$D_v = W \div [V(T_1 - T_0)]$$

where

W = the work done on or by the gas in foot-pounds
V = the volume in cubic feet
D_v = the dynamical value in foot-pounds

It is evident that the method of operation just described affords a means of determining the heat-loss on expansion or compression-lines, and so permits the temperature fall or rise, due to the work done, to be determined at any temperatures. In this way I have experimented on the products of combustion contained within the gas-engine cylinder, and deduced the values of D_v for that working fluid at different temperatures. The experiments were numerous, and many difficulties were encountered; for the full discussion I refer to the paper[11] describing the experiments read by me before the Royal Society in 1906. It is sufficient here to give the values obtained for the working fluid, which was of the following composition:

	Percentage by Volume
Steam (assumed gaseous)	11.9
Carbon dioxide	5.2
Oxygen	7.0
Nitrogen	75.0
	100.0

TABLE 6—APPARENT INSTANTANEOUS SPECIFIC HEATS IN FOOT-POUNDS PER CUBIC FOOT OF WORKING FLUID AT 0 DEG. CENT. (32 DEG. FAHR.) AND 760 MM. (29.92 in.)

Temperature, deg. cent.	Temperature, deg. fahr.	Specific Heat at Constant Volume. ft-lb.
0	32	19.60
100	212	20.90
200	392	22.00
300	572	23.00
400	752	23.90
500	932	24.80
600	1,112	25.20
700	1,292	25.70
800	1,472	26.20
900	1,652	26.60
1,000	1,832	26.80
1,100	2,012	27.00
1,200	2,192	27.20
1,300	2,372	27.30
1,400	2,552	27.35
1,500	2,732	27.45

the charge. The gas present in the charge is known to be approximately 0.183 cu. ft. at the working temperature of the measuring meter, and its lower calorific value was 574 B.t.u. per cu. ft. The heat of combustion of the gas is therefore $0.183 \times 574 = 105$ B.t.u. It is thus seen that the approximation is very close. The indicator has been able by the new method of application to account for the heat present in the charge.

TABLE 8—HEAT BALANCE-SHEETS FOR "X" ENGINE PREPARED FROM CLERK DIAGRAMS.

Card No.	22		23		24		Mean of the Three Cards
Heat-flow during Explosion and Expansion	Ft-lb.	Per cent	Ft-lb.	Per cent	Ft-lb.	Per cent	Per cent
Heat Contained in Gases at End of Expansion	12,480	15.4	14,000	17.0	13,100	16.0	16.1
Indicated Work	39,800	49.0	40,500	49.3	40,600	49.5	49.3
Total Heat	28,900	35.6	27,700	33.7	28,260	34.5	34.6
	81,180 (104 B.t.u.)	100.0	82,200 (106 B.t.u.)	100.0	81,960 (106 B.t.u.)	100.0	100.0

From cooling curves determined during the actual operation of the piston in the gas-engine cylinder in the manner described, and the dynamic value of the temperature-falls at high and low temperature in foot-pounds per standard cubic foot of working fluid, calculated from my specific-heat values as given in Tables 6 and 7, balance-sheets of the engine have been prepared from indicator measurements only. No gas measurements or determinations of heat-flow to jacket-water are required. Three diagrams were taken at full load of 50 b.hp., from which the balance-sheets in Table 8 were calculated.

All the values have been taken in foot-pounds. Taking Card No. 22, for example, the heat-loss due to cooling is equal to 12,480 ft-lb., the heat contained in the gases at the end of the expansion is equal to 39,800 ft-lb., and the positive loop of the indicator-diagram shows that the work done on the piston is 28,900 ft-lb. Now, if we add together these three items, we should get the total heat given to the charge for one stroke of the engine; this amounts, it would seem, to 81,180 ft-lb., which is equivalent to 104 B.t.u. Cards 23 and 24 vary slightly from this, but they each show 106 B.t.u.

If the combustion is nearly complete at the end of the stroke, the heat present found in this way should be equal to the heat evolved by the gas known to be present in

The distribution of the heat varies to a small extent in the three diagrams, so that it is better to consider the mean result at the extreme right. In this balance-sheet each item is directly determined by a separate measurement, and no item is obtained by a difference as in the earlier balance-sheet. It is interesting, however, to compare a mean diagram taken by my optical indicator from the 9 x 17-in. gas engine at full load with hot-water

TABLE 7—MEAN APPARENT SPECIFIC HEATS IN FOOT-POUNDS PER CUBIC FOOT OF WORKING FLUID AT 0 DEG. CENT. (32 DEG. FAHR.) AND 760 MM. (29.92 IN.)

Temperature deg. cent.	Temperature deg. fahr.	Specific Heat at Constant Volume. ft-lb.
0- 100	32- 212	20.3
0- 200	32- 392	20.9
0- 300	32- 572	21.4
0- 400	32- 752	21.9
0- 500	32- 932	22.4
0- 600	32-1,112	22.8
0- 700	32-1,292	23.2
0- 800	32-1,472	23.6
0- 900	32-1,652	23.9
0-1,000	32-1,832	24.1
0-1,100	32-2,012	24.4
0-1,200	32-2,192	24.6
0-1,300	32-2,372	24.8
0-1,400	32-2,552	25.0
0-1,500	32-2,732	25.2

[11] See *Proceedings of the Royal Society*, vol. 85, p. 1.

jacket. A balance-sheet prepared by measuring the temperature-drop for the exhaust heat and the positive loop for the indicated power and deducting their sum from the total heat known to be present, is as follows:

	Per Cent
Heat-flow during Explosion and Expansion (by Difference)	21
Heat Contained in Gases at End of Expansion.	47
Indicated Work	32
	100

This balance-sheet, from a smaller engine, differs but slightly from the values calculated by my method which has been discussed. My mean balance-sheet, however, differs considerably from a balance-sheet calculated for the 14 x 22-in. engine at full or nearly full load by the Thermodynamic Standards Committee of the Institution of Civil Engineers, whose measurements consisted of brake horsepower, heat carried away by the water-jacket and radiated from the engine and heat discharged with the exhaust as determined by an exhaust calorimeter placed so as to cool the exhaust gases after passing out of the engine cylinder, all items being separately determined. The Committee's balance-sheet is compared with mine in Table 9.

TABLE 9—COMPARISON OF HEAT BALANCE-SHEETS

	Committee's Trials	Clerk Diagram Trials
Heat-flow during Explosion and Expansion	25.4	16.1
Heat Contained in Gases at End of Expansion	39.9	49.3
Heat in Indicated Work	34.7	34.6
	100.0	100.0

This discrepancy is mainly due to the fact that in ordinary trials the heat passing into the water-jacket system includes not only the heat-loss during explosion and expansion while the cylinder is entirely closed, but also heat from the exhaust gases, which passes into the jacket after the exhaust-valve opens during the exhausting stroke. This I have already explained.

From this discussion it is evident that heat-loss to the cylinder walls is much less than is popularly supposed in engines of modern design. It is often believed by inventors that one-half of the whole heat of the fuel passes away through the walls, and many schemes for working with red-hot walls have been, and, indeed, are sometimes yet, proposed under the idea that a great increase in thermal efficiency is possible by saving wall-loss. As a matter of fact, only a comparatively small increase in thermal efficiency is possible even if the whole of the wall-loss could be prevented.

I have made calculations from my own table of specific heats, which was fully discussed at the Institution of Civil Engineers some years ago, and they prove conclusively that in the National engine referred to, complete elimination of all heat-loss during explosion and expansion, using the compression-ratios and combustion temperatures actually attained in the working of the engine, would give an indicated thermal efficiency of 39.5 per cent instead of 34.7. That is, the actual engine gives 88 per cent of what an ideal engine of the same expansion, and using the same working-fluid, could give with heat-losses assumed to be absent. I have calculated the ideal efficiencies for different compression-ratios, assuming no heat-loss to walls, for maximum temperatures of 1600 and 1000 deg. cent. (2912 and 1832 deg. fahr.), with working fluid having variable specific heat according to my values, and for air standard having constant specific heat at all temperatures.

TABLE 10—IDEAL EFFICIENCIES WITH APPARENT SPECIFIC HEATS GIVEN BY CLERK'S EXPERIMENTS

$1/r$	Maximum Temperature 1600 deg. cent. (2912 deg. fahr.)	Maximum Temperature 1000 deg. cent. (1832 deg. fahr.)	Air Standard
1/2	0.195	0.200	0.246
1/3	0.286	0.293	0.360
1/4	0.354	0.356	0.430
1/5	0.384	0.394	0.480
1/7	0.439	0.443	0.550

From this table it will be seen that for a given compression-ratio the efficiency of air at constant specific heat is the highest, and that with varying specific heat, the lower the maximum temperature the higher the efficiency. For example, with a compression space of one-fifth the total volume, the air-standard efficiency is 0.48; working fluid of varying specific heat at 1000 deg. cent. (1832 deg. fahr.) maximum temperature, ideal efficiency 0.394, and at 1600 deg. cent. (2912 deg. fahr.) maximum temperature, ideal efficiency is 0.384. With both working fluids the ideal efficiency increases with increasing compression, and with the actual working fluid without any heat-loss, the efficiency increases as the temperature falls. The greater the specific heat, the lower is the thermal efficiency for a given expansion.

Another test was made with the same gas engine. In this case, however, the engine was driven electrically at 120 r.p.m., while the jacket was kept cold and the charge was taken from a large chamber which enabled its exact temperature to be measured. In this way it was possible to determine the suction temperature with accuracy. The important temperatures were (*a*) suction temperature 20 deg. cent. (68 deg. fahr.), (*b*) compression temperature 214 deg. cent. (417 deg. fahr.), (*c*) maximum explosion temperature at about 1/20 forward stroke 1380 deg. cent. (2516 deg. fahr.) and (*d*) temperature of exhaust in the cylinder before opening the exhaust-valve 650 deg. cent. (1202 deg. fahr.). The diagram was carefully taken by the same optical indicator. The balance-sheet as calculated is given in Table 11.

TABLE 11—HEAT BALANCE-SHEET OF A LARGE GAS ENGINE

	Per Cent
Heat-Flow during Explosion and Expansion.	37
Heat in Gases at End of Expansion	35.5
Indicated Work	27.5

The indicated work fell from 32.0 per cent to 27.5 and the heat-flow during explosion and expansion rose from 21.0 to 37.0 per cent as the result of work, the same mixture with a cold charge in a cold cylinder.

Conclusion

There are many questions which I have not dealt with, particularly the greatly increased mean-pressures obtained in the gasoline engine as compared with gas engines. The conditions of maximum thermal efficiency are the same for gas and gasoline. The fact that gaseous explosions are subject to a contraction of volume by the formation of carbonic acid gas and water, while hydrocarbons such as gasoline give a larger volume on combustion, would itself give increased mean-pressures, but

in addition the total heat-content of a gasoline-engine charge is over 100 B.t.u. per cu. ft. instead of 80 which is now the maximum with coal-gas; this also will cause further increase.

For full consideration of these points in England I look to my friend H. Ricardo who has written many valuable papers and made elaborate experimental investigations into the conditions of the maximum gasoline-engine thermal efficiency and output. He is at present completing a careful investigation into the characteristic features of different liquid fuels and is experimenting on the subject of knocking or detonating. Part of his work has been published and you are doubtless familiar with it. I am assisting by discussing the subject with Dr. Stanton and Mr. Fenning of the National Physical Laboratory. Interesting work on detonation is in progress there which will be published in due course.

Meantime it is difficult to say what causes a gaseous explosion to pass into detonation. I pointed out long ago that my early experiments with the explosion of compressed mixtures up to about 60 lb. above atmosphere, together with Sir Joseph Petavel's experiments up to 1100 lb. per sq. in., clearly show that increased compression in itself does not cause detonation. My experiments on suction turbulence with a hot engine and a hot mixture prove conclusively that higher temperature does not cause detonation. It seems that more recent experiments in closed vessels also point in the same direction. Auto-ignition by compression of piston or flame can raise the temperature of the whole body of the mixture to the igniting point and if ignition started equally from every point we should expect detonation or something very like it. Prof. Harold Dixon's experiments seem to show, however, that when auto-ignition starts it starts from one point and not from every point. Other experiments on this subject also are being made by Mr. Ricardo.

Purely chemical constitution undoubtedly causes knocking which may or may not amount to detonation in the sense of Berthelot's explosive wave. The difference may arise, as pointed out by Thomas Midgley, from the endothermic compared with the exothermic hydrocarbons.

I have already pointed out that knock can be got with any fuel by mechanical disturbance, and it may be possible that the reduction of total volume by increased compression may produce knock without increasing the rate of flame propagation simply by diminishing the distance of flame travel. For that the only remedy which I can suggest from present knowledge is the use of cold exhaust-gases either by exhaust-gas supercompression or by mixture with the incoming charge.

I look forward with much interest to the discovery of new facts by the younger engineers and scientific men of America and England. I am delighted to find that American engineers and chemists are doing so much good work in forwarding the solution of many difficult problems. Internal-combustion-engine problems fascinated me 44 years ago and my interest and wish to continue experimenting still last. It is a very great pleasure to feel that the brilliant American engineers, chemists and physicists of this great Society have taken up the good work which even in its early stage has wrought such important changes in the world.

RESEARCH WORK ON GEARS NEEDED

SUCCESS in designing gear drives to operate satisfactorily under specified conditions is very largely a matter of appreciation of what has been done before under very similar conditions. The Lewis formula, being a formula for strength only, is of no assistance in selecting the most suitable combination of pitch, diameter, face width and material for the purpose. Experience only can determine these proportions, because, even though the gears be made to a fine degree of accuracy, and be capable of transmitting the load without tooth breakage, it does not necessarily follow that they will give complete satisfaction when they are placed in operation.

Further investigation could be made to advantage to establish reliable data relative to the various factors that determine the smooth operation and life of gear trains. The research could be divided into three sections. The work in section one would be to establish the most suitable material for use under given conditions, the allowable stress, the allowable pressure, the resistance to abrasion, the elasticity and such things being found for different materials. Investigation in section two would deal with methods of manufacture, and an attempt would be made to define the degree of error permissible for various grades of workmanship. Research in section three would determine the influence upon the life and quiet operation of gears of such variables as peripheral velocity, load per unit of breadth, number of impacts, ratio of reduction, grade of workmanship, heating, and the disposition of metal in the gear rims and arms. Methods of gear mounting to absorb vibration, and the lubrication of gears would receive attention.

It will be agreed that successful research work along these lines would provide dependable data for the design of gears to meet any conditions in regard to load, speed, quiet running, life and such points. Alone, the Lewis formula can be used only to ascertain the maximum permissible load to insure freedom from tooth breakage; and, unfortunately, with many gears this is the only point checked by the gear designer, with the result that they are transmitting excessive pressure, so that backlash and noise develop in a short time. —R. J. Chapman in *American Machinist.*

AUTOMOBILES AID ALL OCCUPATIONS

EVERY business, every profession, gains through use of the automobile, according to the answers received by the National Automobile Chamber of Commerce to thousands of questionnaires sent to car owners throughout the country. Farmers show a gain of 68 per cent in their individual efficiency. This is an especially important figure, as the farmer is the largest class of car owners. Farmer-owned cars total over 2,500,000 or nearly one-third of all cars in use.

Bankers in rural districts find their cars productive in passing on mortgages and in getting acquainted with their out-of-town trade. The heavy gain here partially offsets the relatively small car utility in these occupations in the large cities where the business is more confined to the office. Manufacturers report a great saving in their time through car use as plants are frequently several miles from their homes, and motoring proves the most efficient means of transportation. Clergymen and school supervisors report a very large gain in the amount of work which they can accomplish.

Some Considerations in Tractor Service

By J. C. Thorpe[1]

Chicago Truck and Tractor Meeting Paper

It requires no little amount of courage to appear before a group of engineers who are so familiar with the technical details of the farm tractor and attempt to present anything on the subject of service. Volumes have been written on the subject and there is scarcely a dealers' or engineers' association program on which it does not have a prominent part. The only reason for a repetition of discussion lies in the fact that we seem to be about as far from reaching our objective as we were several years ago. It is entirely probable that if we were to take a vote of this meeting, it would be very difficult to secure the opinions of any considerable number that might approve a definition of what we call "service." You will understand, therefore, that I do not have in mind the presentation of any new facts. It may be possible to dress up some of our present arguments in a little bit different attire so that their importance may be more strongly emphasized upon our mind. It is my purpose to present the subject in three phases: (*a*) general consideration, (*b*) the commercial aspect, and (*c*) the technical aspect.

General Considerations

One subject is very closely related to a question that has been very much discussed in the trade press and upon the floors of dealers' conventions during the past 3 or 4 years. This refers to, "Who is the logical tractor dealer?" Two groups have been involved in these discussions and have taken positions almost immeasurably apart. The old-time implement dealer says that he is the logical tractor dealer because he has been selling to the farm trade for years. He knows the farmer and his problems; also his habits of buying and selling. He is sure that irrespective of other considerations his own farm trade will buy tractors from him and from none else. He states, with emphasis, that no other merchant should encroach upon his territory and that the tractor factories should give him precedence over all others. The automobile dealer claims that he is the logical one to merchandise tractors because this equipment has very definite service requirements and he is thoroughly educated in taking care of the needs of those in his community who use automotive equipment. In my opinion all of this discussion has been misdirected and has failed entirely to reach the point. The dealers mentioned have failed to recognize the essential qualifications of a merchant in any mercantile community, namely, the ability to merchandise good goods at fair prices properly and having consummated sales to occupy the position of a consulting expert in relation to the customer.

It is not important that the old-time implement dealer is familiar with the farmer and his problems, nor that the automobile dealer has been trained in the art of giving service, when considering the substantial qualifications of a real merchant. Whoever of these groups measures his right to sell by the standard I have indicated to be the proper one is the logical tractor dealer. Because of the universal appeal of the farm tractor to the farming interests of the country, the sale of farm tractors offers opportunities for the development of "good-will" that are unequalled by any other merchandising activity. This very tangible asset is the essential cornerstone upon which the structure of every successful enterprise is built. It is always evident in thoroughly businesslike and fair dealings between the buyer and the seller and becomes intensified in the development of subsequent satisfactory business relations. The manufacturer, by producing an article of merit, honest advertising and a long period of fair treatment of the dealers, cooperating with them in promoting the interests of the customer, gradually attracts to himself and to his product a certain amount of public interest and approval. This degree of public approval is the measure of the manufacturers' good-will account. It is developed only by careful, honest and persistent effort through a period of years, but it may be destroyed by one false step.

We often hear, "What's in a name?" In my opinion that dealer who does not continually strive to make his name mean something in his community that will add to the economic wealth is missing what might be termed his logical objective and his right to permanency in his community may readily be questioned. Marshall Field has become a name to conjure with in the homes of this country, because of an attitude toward the customer based upon the conclusion that "the customer is always right." You are brought face to face upon the streets of St. Louis with the slogan "Don't say paper, say Star." My conclusion is that a tractor dealer should so persistently pursue the highest type of merchandising methods that his name will be inseparably identified in the mind of his market with the farm tractor. This result may be anticipated if the dealer outlines and carefully carries out a program that creates an impression of his thorough understanding of the subject and the adequacy of his service organization. Fundamentally, this conclusion is based upon the principle that tractor service meets an economic need; and to him who satisfies this need will come the reward of an enlarged and increasingly profitable business.

Cooperation between the dealer and the manufacturer is necessary in carrying out this program. The manufacturer is not a very tangible factor in the investment, judged from the standpoint of the purchaser, who seldom, if ever, comes in contact with the factory organization. And, while the manufacturer is dependent upon the good-will of the trade, as stated before, he must arouse public interest and approval through his intermediate trade factor, the dealer or distributor. This involves the maintenance of an adequate stock of repair parts, an efficient service and inspection department and an attitude of favorable forbearance with respect to service claims. It is the dealer to whom the customer looks for relief when equipment fails to measure up to his expectations, either in performance or in the quality of materials or workmanship. It is this mental attitude on the part of the buyer that often places the purchase upon the basis of a selection of the dealer rather than upon a selection of the specific item of equipment or merchandise. It is thus that the ability to "keep goods

[1]Barnett & Wilson Investment Co., St. Louis, Mo.

sold" becomes of equal importance with the art of selling, and presents a problem in which both manufacturer and dealer are vitally interested.

The Commercial Aspect

"Service" has become the pet slogan, expressed or implied, of nearly every business organization. It has been rolled like a choice morsel under the tongue of factory managers, accessory and supply jobbers, implement dealers, garage operators, crossroad repair shops and salesmen alike. It is to be regretted that claims to service superiority have not always been supported by a service plan tended to justify them. Despite the apparent familiarity with this magic word, it can be stated with assurance that it has almost challenged definition. I seriously question whether any considerable number of us here would spontaneously approve any definition that one of us might present. In the mind of the automobile owner it has meant anything from a "cursory once-over" accompanied by a copious discharge of so-called expert advice, to a semi-annual overhauling during the life of the car, without expense to the owner. Quite innocently, the term "service," whatever it may be understood or misunderstood to be, has become the vehicle of the most pronounced fallacy in the merchandising of machinery, damaging to manufacturer, dealer and customer; namely, the possibility of getting something for nothing. "Service" has been paraded in most alluring dress before the mind of the prospective purchaser by the unscrupulous salesman to the extent of creating an expectation of expenseless ownership. The rude awakening of the owner discredits the salesman, the dealer, the manufacturer and the product. There can be no such thing as free service. Such a conception is opposed to the economic law of compensation. To give service requires time and money, labor and materials, and for these someone must pay. In the end it is the consumer, because in the chain of trading events all the money must come from him.

The success of every merchandising enterprise is largely dependent upon the interpretation of this word service. Satisfying service for reasonable compensation always develops good-will between the seller and buyer. It goes far toward making the enterprise impregnable to the assault of depressing business conditions. If an article has merit, if it meets an economic need, somewhere there is someone with the inclination and the ability to buy, if he has the opportunity. Business depression may diminish volume and greatly increase selling costs and thus reduce profits but it does not completely destroy selling opportunities. A reputation for honest manufacturing, for courteous and courageous salesmanship and for rendering satisfying service can be expected to bring its reward in maintaining an open channel of trade when times are "hard," and a continually increasing volume of trade, the goal of every ambitious enterprise, in periods of normalcy. The bugbear free service often introduces factors of abuse and unfairness in competition. Sales are often made, apparently upon the basis of "who can give the most away." After the gross profit disappears in the negotiations, "free service" enters to bait the unsuspecting prospect further. It destroys confidence, separates business associates, debauches business character and attacks industrial progress. It makes impossible that close cooperation among dealers that is most healthful for trade development. It cheapens the product of the manufacturer and reflects discredit upon his selling organization. The term service, properly understood, thus loses its identity with the appearance of unfair trade tactics. If the purchaser, either through a misunderstanding of the service obligations of the dealer or by forethought, asks for and receives concessions incompatible with good business procedure, a fictitious value is placed upon the goods sold. Such a value cannot be maintained and thus another phase of price-cutting is introduced that is ruinous, not only to the individual dealer but to the industry. It would appear that the following definition may be a proper one:

> *Service*, as applied to the operation and maintenance of power-farming machinery, is the cooperation of the dealer with the owner, whether he be the original purchaser or not, during the life of the equipment in the dealer's district, to the end that the owner may secure continuous use of his investment at the lowest reasonable cost.

We all recognize that service is arousing the same general discussions in assemblies of representatives of the tractor interests that have been prevalent for years in the automobile industry. Unless the present agitation is curbed and thought directed by the leaders in the power-farming-equipment field along the lines of reason and good sense, it is probable that we shall experience the same difficulties and pass through the same period of chaos that has characterized the development of the motor-car.

Some confusion frequently arises in the interpretation of the factory warranty covering parts that fail due to faulty workmanship or material. Today, this warranty is limited to the replacement of such parts after they have been shipped to the factory, charges prepaid, inspected by the factory inspection department and found to come under such warranty. Repair parts are then shipped to the dealer or owner as the case may be, f.o.b. the factory shipping point. There are occasional departures from the factory policy of paying no labor charges. A clear and positive understanding of this warranty between the factory and the dealer, and through the latter, with the customer, is essential for the purpose of eliminating discussions with owners that often become embarrassing to all parties concerned and damaging to business.

Many factories maintain a corps of skilled mechanics who cover the territory to extend mechanical service to dealers with incompetent or no service men or to isolated owners who cannot appeal to the local dealers for service. The maintenance of this group of mechanics involves a material expense for which the manufacturer must be compensated. In most instances contracts do not differentiate between the dealers with adequate service facilities and those without. It is clear that this policy places a premium upon inadequate service and offers no encouragement to the improvement or development of service facilities.

It is a serious question whether we are near enough right in the present status of the factory warranty to begin the consideration of improved service with the conditions existing in the dealer body. My opinion is that a system of merchandising must be developed whereby a premium is placed upon adequate dealer service. This can be expected to place an ideal before the careless merchant that should prove an inspiration to attain to a higher plane of service activity. It should go far in attracting into the industry men of real commercial ability and achievement.

There are certain principles of design that appeal to the sales engineer, along the lines of which you are undoubtedly directing your energies. A tractor should possess such ease of control and operation as to make the employment of skilled labor on the farm unnecessary. I have frequently run across farmers who have persistently refused to consider the purchase of a tractor because they felt there was no one on the place to run it. The tractor should be of such pronounced simplicity and accessibility of mechanical detail as to guarantee a minimum loss of time and money for needed repairs, replacements or adjustments. It should have proved economy of operation and maintenance in order that it can make an appeal to the purchaser from the angle of an investment. The designer should have constantly in mind the fitness of the machine for the work it is proposed it shall do. It is to be regretted that this particular quality has been too much neglected in the tractor field with respect to design and to the selling policy of the factory and the dealer. I am convinced that much of the unfavorable criticism of the tractor has come from the fact that the purchaser was sold equipment that was unsuitable for his requirements.

I have been astonished at the lack of attention to what I consider a most important detail, the comfort of the operator. Salesmen talk loud and long about the merit of power-farming equipment as it relates to independence of weather and labor conditions. The farmer may await the arrival of settled weather before he begins his work and then by working 20 to 24 hr. a day catch up with his neighbor who is utilizing antiquated horsepower. The fact that he is to sit in a cramped position from sun-up to sun-down under the direct rays of a broiling sun upon a malleable iron seat upholstered in black enamel is never mentioned. No arnica or liniment is sold with the tractor and yet this is about as necessary an accessory to the machine as oil or water.

Frequent and expensive interruptions in service are occasioned by delay in securing repair parts. However careful the dealer may be to maintain his parts stock, occasions will arise when he must appeal to the factory for assistance. Frequently this assistance is not given promptly because no parts are available from the factory stock. This presents a production problem that must have attention if power farming is to receive the approval it warrants. It would seem that the great desire for the production of completed units has obscured the question of what shall be done for them after they are sold and put to work. A proper scheduling and control of parts production should eliminate this difficulty. Too little attention is given the dealer in the selection of his parts stock. The industry is too young and the experience of the dealers too limited to expect the exercise of accurate judgment respecting parts requirements. It is highly desirable that this problem be given careful consideration by the engineering departments, in the preparation of parts lists based upon actual field experience, which can be placed in the hands of the dealers when executing their contracts.

Some of the most conspicuous successes in the industrial development of our country have been based upon the development of a training school within the enterprise. I have in mind the many special apprenticeship courses that are available for those requiring special training within either the parent organization or its external connections. Service will not be organized upon the most desirable plane until men are available who will take their places as skilled mechanics in the great dealer organization. Some hit-and-miss plans of training tractor mechanics are in operation in several factories at this time. The manufacturer of power-farming equipment who gets a real vision of this problem and outlines a definite program of specialized training for tractor mechanics or service men, will secure a wonderful asset. The organization of service schools by the tractor companies shows an appreciation of the problems in operation and maintenance that confront the tractor operator. The principle is right, the motive commendable, but the method wrong in most instances, in my opinion. Too little attention is given to differentiating between field operations and service station or shop operations. It is not wise, except in rare instances, to encourage the farmer to undertake service-station operations with the inadequate shop facilities existing on the average farm. And yet it seems that most of the instructors in charge of the mechanical-service schools place the greatest emphasis on taking magnetos apart, charging the magnets and reassembling the unit, taking down the crankcase and refitting bearings, etc., giving entirely too little attention to emergency field operations and ordinary inspection.

Most of the problems presented would respond to a closer cooperation between the sales and the engineering departments. This should develop a greater sympathy between the departments relating to the difficulties that are of mutual interest. Greater interest of the engineer in field activities would go far toward a solution of mechanical service as it relates to the design, and a keener interest in the problems of the engineer on the part of the sales department would unquestionably enhance the effectiveness of the selling campaign.

I can think of no development that would be of more permanent and immediate benefit to this great industry than the organization in every factory of a merchandising and engineering research department that would link up and conserve the energies of selling and production. In its relation to service, this department would be of incalculable value to the dealer, and if to the dealer, to the American farmer who yet needs to be "sold and kept sold" on the power-farming idea.

HIGHWAYS

IT has been found that a tax for a well-prepared highway is less of a burden than the age-long discouraging mud tax which has been one of the greatest drawbacks in rural development everywhere.

Successful rural education, as exemplified in the modern consolidated schools, cannot be conducted with a real measure of success unless from each school there radiate from 30 to 50 miles of good roads, over which autobuses rapidly course their way with their loads of children and youth, back and forward from school and home.—P. P. Claxton.

MARCH 1921 ISSUE OF DATA SHEETS

THE March 1921 data sheets containing the revisions and additions which were adopted by the Standards Committee in January were mailed to the members early in May. Members who have not done so should sign and mail the return postal card enclosed with each set.

Elements of Automobile Fuel Economy

By W. S. James[1]

Semi-Annual Meeting Paper *Illustrated with* Charts and Diagrams

THE viewpoint from which this paper has been written has been purely analytical. An attempt has been made, first, to analyze and state the factors affecting the power requirements of cars as rubber-tired vehicles of transportation over roads; second, to analyze and state the factors affecting the amount of power supplied the car as fuel to produce at the road the power required for transportation. Wherever possible, quantitative values have been given to indicate our present knowledge of the relations between the factors involved.

The power required to propel rubber-tired vehicles over roads is delivered to the road by the wheels as thrust or tractive force which is used (*a*) to overcome wind-resistance, (*b*) to overcome the resistance to the rolling of rubber-tired vehicles, (*c*) to produce linear acceleration of the car masses and angular acceleraton of the wheels and (*d*) to overcome gravity deceleration when climbing hills.

The thrust or tractive force required to overcome wind-resistance is proportional to the projected frontal area of the car and to the square of the velocity of the car relative to the air. Stated symbolically

$$F = CAV^2$$

where

A = Area in square feet
C = Constant of proportionality
F = Force in pounds
V = Velocity in miles per hour

The constant of proportionality C varies with the type of body and no reliable information seems to be available on the effect of changes in body shape on this figure. Values of C from various sources are given in Table 1. The measurement of the projected frontal area of 17 different representative makes of car gave an average value of 26 sq. ft., the minimum being 24 and the maximum 30 sq. ft.

The thrust or tractive force required to overcome the road-resistance to rolling of rubber-tired vehicles is nearly independent of speed (See Table 2) and depends on (*a*) the weight of the vehicle, (*b*) the character of the road surface, (*c*) the construction of the tires, (*d*) the inflation-pressure of pneumatic tires and (*e*) on the type of wheel-bearings. As the last three items vary directly with the weight of the car, numerical values for the tractive force necessary to overcome the rolling resistance are usually given in terms of pounds of force per 1000 lb. of car weight or per ton of car weight. The former unit will be used in this paper. The rolling resistance of rubber-tired vehicles over different types and conditions of road surface varies widely. Values of this resistance from various sources are collected in Table 3. There is little information available as to the effect of tire construction on rolling resistance. The values in Table 4 indicate the magnitude of the variation in resistance to be expected. Little has been published on the resistance of different types of wheel-bearings and on the effect of the type of lubricant used and its temperature. Values obtained by Lockwood and Riedler are given in Tables 2 and 5. Table 2 indicates that bearing resistance probably increases in proportion to the speed. It is however, a small percentage of the total rolling loss. In Table 5 it is assumed that in the case of a six-cylinder Chalmers chassis the bearing losses in the front and rear wheels are equal. The load on the front wheels was 1145 lb. and 1545 lb. on the rear wheels. The tires were 32 x 4 in. and the inflation-pressure was 74 lb. per sq. in.

TABLE 1—VALUES OF CONSTANT C FOR WIND-RESISTANCE

Source	Value of C
Hunsaker, Marks' Handbook[2]	0.00328
Riedler, The Scientific Determinations of the Merits of Automobiles	
Electric Vehicle with Closed Body[3]	0.00318
30 hp. Renault Car with Open Body[3]	0.00324
40 hp. Daimler with Open Body[3]	0.00324
Browne and Lockwood[4]	0.00300
Favary, Motor Vehicle Engineering[5]	0.00400
Heldt, Marks' Handbook[6]	0.00420
Hütte[7]	0.00275

[2] This value is based on a flat plate from 5 to 10 ft. square normal to the wind. It is hardly possible that the coefficient of an automobile would exceed that of a flat plate as there are few shapes used with larger coefficients.

[3] These values were used to compute car performance from test-stand results. All other resistances were measured. Road-performance tests of cars checked laboratory results remarkably well.

[4] See Transactions, vol. 10, part 1, p. 68. Road tests on one car to check test-stand results showed power actually required on road to be 2 per cent higher at 20 m.p.h. and 5 per cent higher at 30 m.p.h. than values computed using this figure. At 30 m.p.h., where the wind-resistance is a large proportion of the total resistance, an increase in the wind-resistance coefficient of 6 or 7 per cent would bring the road tests in agreement with the stand tests and the coefficient close to Riedler's figures.

[5] Data for flat plates from United States Signal Service at Mt. Washington, N. H. This value is probably high.

[6] Probably high; see last sentence in footnote 2.

[7] Taken from wind-resistance of fast trains. Probably low for automobiles because of the length of even a short train.

The data presented show that for a given car-weight the variation in road-surface resistance is by far the most important item to consider in the reduction of rolling resistances.

The tractive force required to give a linear acceleration to the mass of the car and an angular acceleration to the wheels is directly proportional to the weight of the car and the weight and moment of inertia of the wheels. The force required to accelerate the wheels is about 2 to

[1] M.S.A.E.—Associate physicist, Bureau of Standards, Washington.

4 per cent of the total tractive force and can be neglected. An acceleration of from 3 to 4 ft. per sec. per sec. is usually demanded in good performance, but accelerations as high as 5 and 6 ft. per sec. per sec. are very uncomfortable for passengers. The tractive force required per 1000 lb. of car-weight for several rates of acceleration, including an additional force of 3 per cent for wheel accelerations, is given in Table 6.

The tractive effort required to overcome grades is equal to the product of the car-weight, gravity acceleration and the sine of the angle of grade. For grades less than 14 per cent the per cent grade can be used in place of the sine of the angle with an inaccuracy of only 1 per cent. For grades less than 6 per cent the error is inappreciable. There seems to be no general rule followed in country road construction for maximum permissible grades. In cities the grades are kept below 10 per cent unless extraordinary conditions must be met. Tractive force per 1000 lb. of car-weight for grades up to 14 per cent is given in Table 7.

To illustrate the relation existing between the three[8] major power demands, wind-resistance, road rolling-resistance and acceleration, the characteristics of the average 1921 American car as given by *Motor*[9] have been computed and the results are given in Table 8. It will be noticed that the tractive force available to overcome

[8] The power or tractive effort required for acceleration and hill-climbing are performance requirements independent of the road surface and wind-resistance. They can be considered as one power-demand interchangeable in application as both are essential accelerations and seldom demanded at the same time. The only point of difference lies in the fact that hill-climbing does not necessarily involve wheel acceleration. This item is small and for the purposes of this illustration can be neglected.

[9] See *Motor*, January, 1921, p. 67.

TABLE 2—RESISTANCE TO ROLLING OF PNEUMATIC-TIRED VEHICLES AT SEVERAL SPEEDS

Car	Speed, m.p.h.	Front Wheel Resistance per 1000 Lb. of Car Weight, lb. Total	Tires	Bearing and Windage	Rear Wheel Resistance per 1000 Lb. of Car Weight, lb. Total	Tires	Bearing and Windage	Total Wheel Resistance per 1000 Lb. of Car Weight, lb.
30-hp. Renault[11]	6.2	5.4	4.5	0.9[12]	...	...	...	23.3
	12.4	5.4	4.5	0.9	17.9	...	...	22.4
	18.7	5.7	4.5	1.2	16.7	...	...	20.4
	24.9	6.1	4.5	1.6	14.3	...	...	19.2
	31.1	6.3	4.5	1.8	12.9	...	...	21.3
	37.3	6.8	4.6	2.2	14.5	...	...	21.3
	43.6	7.4	4.6	2.8	17.1	...	...	24.5
40-hp. Daimler[10]	6.2	6.4	5.6	0.8[12]	...	...	...	...
	12.4	6.4	5.6	0.8	...	...	...	...
	18.7	7.0	5.9	1.1	16.6	...	...	23.6
	24.9	7.3	5.7	1.6	17.3	...	...	24.6
	31.1	7.7	5.8	1.9	17.4	...	...	25.1
	37.3	7.8	5.4	2.4	18.0	...	...	25.8
	43.6	8.6	5.8	2.8	18.9	...	...	27.5
	49.7	9.0	5.8	3.2	18.3	...	...	27.3
Mercedes Electric[16]	6.2	7.4[11]	...	...	14.5[11]	...	...	21.9
	12.4	7.9	...	...	14.7	...	...	22.6
	18.7	8.4	...	...	15.8	...	...	24.2
	24.9	8.9	...	...	17.9	...	...	26.8
	31.1	9.2	...	...	21.5	..	...	30.7
45-hp. Bussing Motor Truck[13]	6.2	3.8	...	...	13.7	8.2[13]	5.5	17.5
	9.3	4.8	...	...	13.3	8.4	4.9	18.1
	12.4	5.3	...	...	13.7	8.5	5.2	19.0
	15.5	5.9	...	...	14.4	10.8	3.6	20.8
100-hp. Benz Racing Car	31.1	7.1	...	...	24.0	...	...	31.1
	43.6	7.6	...	...	30.0	...	...	37.6
	55.9	5.9	...	...	31.0	...	...	36.0
	68.4	10.4	...	...	31.0	...	...	41.4
	80.7	13.6	...	...	31.0	...	...	44.6
	93.3	14.0	...	...	29.0	...	...	43.0
75-hp. Adler Racing Car[14]	24.9	**10.7**	...	...	34.7	...	...	45.4
	37.3	10.7	...	...	35.6	...	...	46.3
	49.7	10.7	...	...	38.7	...	...	49.4
	62.1	12.8	...	...	36.3	...	...	49.1
	74.7	10.7	...	...	36.5	...	...	47.2

Car	Tires	Inflation-Pressure, lb. per sq. in.	Speed, m.p.h.	Rolling Resistance of Front Wheels per 1000 Lb. of Car Weight, lb.
A[11]	32x4 Silvertown Cord	60	20	10.4
			30	10.4
			40	12.3
B[11]	32x4 Plain Fabric	55	21	21.1
			27	21.8
			34	20.5
			41	21.3
C[11]	35x5	60	21	15.7
			27	16.0
			34	16.3
			41	16.1

[10] See Scientific Determination of the Merits of Automobiles by A. Riedler.

[11] Power Losses in Pneumatic Tires by E. H. Lockwood, published in the TRANSACTIONS, vol. 12, part 1, p. 377.

[12] Annular ball bearings on the Renault and Daimler cars.

[13] Dual solid tires on rear wheels and single solid tires on front wheels.

TABLE 3—RESISTANCE TO ROLLING OF PNEUMATIC-TIRED VEHICLES OVER VARIOUS ROAD SURFACES

Road Surface	Condition	Rolling Resistance per 1000 Lb. of Load, lb.	Authority
Concrete		9 to 19	*A*
Asphalt	Good	7	*B*
	Hard Smooth	11	*C*
	Poor	13	*B*
	Pavement	21 to 31	*D*
Wood	Paving	13	*B* and *C*
Macadam	Smooth and Dry	15	*D*
	Good	17	*C*
	Best	19 to 21	*B*
	Slightly Defective Reasonably Dry	18	*D*
	Good, Softened by Rain	20	*D*
	Dry and Dusty	21 to 24	*E*
	Slightly Defective, Softened by Rain	22	*D*
	Ordinary	22 to 27	*B*
	Hard Best, Wet	24 to 32	*E*
	Bad State of Repair	25	*D*
	Good, Softened	35	*E*
	Soft	43	*B*
	Bad	22 to 45	*C*
Dirt	Dry and Good	15	*D*
Belgian Block	Irregular	22	*D*
Granite Block	Good	27	*F*
Flint	Rolled	37	*F*
	Soft	46	*F*
Cobbles	Ordinary	58	*B*
	Bad	up to 110	*C*
	Very Bad	110	*B*
Clay	Hard Dry	45	*B*
	Best	49	*B*
Gravel	Best	25	*B*
	Loose	75 to 100	*D*
Sand	Road	160	*B*
	Loose	250	*B*
Railroads		4½	*B*
Tramways		13	*B*
"Good" Roads		18 to 22	*G*
Asphalt		10	*B*
		18	*F*
Macadam		27	*F*
"Heavy" Roads		27 to 39	*G*
Cobbles		27	*B*
		26	*C*
Sand		150 to 200	*D*
		160 to 250	*C*

List of Authorities

A Practical Testing of Motor Vehicles by A. B. Browne and E. H. Lockwood, published in the TRANSACTIONS, vol. 10, part 1, p. 68.
B Diagrams for Automobile Power Calculations by George Watson, published in *American Machinist*, Dec. 20, 1906, p. 806.
C Motor Vehicle Engineering by E. Favary.
D M. Forestier in Proceedings of Second International Automobile Congress held at Paris in 1902.
E H. Rodier in *Automobile*, vol. 13.
F The Auto Engineers Year Book, for 1920.
G Accelerometer Tests by H. E. Wimperis, published in *Proceedings of the Institution of Automobile Engineers*, vol. 8, p. 281.

wind and road-resistance and produce acceleration varies less than 4 per cent over the driving range of speeds from 10 to 35 m.p.h.; that the tractive force available to overcome rolling resistance and produce acceleration varies more than 25 per cent over the same range of speeds; and further that grades of from 9 to 4.5 per cent can be negotiated at speeds from 20 to 35 m.p.h., dependent on the road-resistance to rolling. Should the car characteristics chosen be representative of the present American product meeting the demands of the driving

TABLE 4—RESISTANCE TO ROLLING OF PNEUMATIC TIRES OF DIFFERENT TYPES OF CONSTRUCTION AND SIZES[14]

Tires	Inflation Pressure, lb. per sq. in.	Total Load, lb.	Resistance per 1000 Lb. of Axle Load, lb.[15]
32 x 4 Front Wheels Silvertown Cord	60	1,120	9
35 x 5 Front Wheels Silvertown Cord	60	2,100	13
32 x 4 Front Wheels Fabric Tires	55	1,140	19
32 x 4 Front Wheels Cord Tires	55	1,140	12

[14] See Power Losses in Pneumatic Tires by E. H. Lockwood, published in the TRANSACTIONS, vol. 10, part 1, p. 377.
[15] Values are reduced 21 per cent to eliminate bearing losses.

public, the performance demands of the public are in no way unreasonable with our roads as they are today.

Fuel conservation from the point of view of power demands of the car would be greatly furthered by a sound, far-sighted good-roads program. The power demands to overcome grade and high average rolling resistance would

TABLE 5—ANALYSIS OF RESISTANCE TO ROLLING OF A SIX-CYLINDER CHASSIS[16]

	Resistance per 1000 Lb. of Car Weight, Lb.
Front tires only	6.8
Rear tires only	6.6
Front bearings only	1.7
Rear Bearings and Transmission	6.7
Total	21.8

[16] See Power Losses in Pneumatic Tires by E. H. Lockwood, published in the TRANSACTIONS, vol. 10, part 1, p. 377.

not only be reduced but, more important still, car-weights could be reduced without any sacrifice of constructional sturdiness. Any reduction in car-weight means an al-

TABLE 6—TRACTIVE FORCE REQUIRED FOR ACCELERATION

Acceleration, ft. per sec. per sec.	Tractive Force per 1000 Lb. of Car-Weight, lb.[17]
0.5	16
1.0	32
1.5	48
2.0	64
2.5	80
3.0	96
3.5	112
4.0	124

[17] An additional 3 per cent is assumed for wheel acceleration.

most proportionate decrease in the power required and therefore in the fuel to supply the power.

The processes involved in the production of power at

TABLE 7—TRACTIVE FORCE REQUIRED TO OVERCOME GRADES

Grade, per cent	Tractive Force, per 1000 Lb. of Car-Weight, lb.
1	10.0
2	20.0
3	30.0
4	40.0
5	50.0
6	59.9
7	69.8
8	79.7
9	89.7
10	99.6
11	109.4
12	119.3
13	128.5
14	138.6
15	148.0

TABLE 8—ROAD CHARACTERISTICS OF THE AVERAGE 1921 AMERICAN CAR

Car Speed, m.p.h.	Available Engine Effort[18] per 1000 Lb. of Car-Weight, lb.	Air-Resistance[19] per 1000 Lb. of Car-Weight, lb.	Thrust Available[20] for Road-Resistance and Acceleration per 1000 Lb.of Car-Weight lb.	Thrust Available for Acceleration with Road-Resistances per 1000 Lb. of Car-Weight of		
				10 Lb.	20 Lb.	30 Lb.
15	107.3	4.9	102.4	92	83	70
16	105.2	1.8	103.4	93	83	73
20	107.6	8.8	98.8	89	79	69
25	106.0	13.4	92.6	83	73	63
30	103.9	19.2	84.7	75	65	55
35	101.2	26.0	75.2	65	55	45
40	98.0	34.1	64.9	55	45	35
45	94.1	43.4	50.7	41	31	21
50	86.8	53.8	33.0	22	12	2

[18] The data used in this computation were a maximum of 33 hp. at 2270 r.p.m.; a transmission and rear-axle efficiency of 85 per cent; the torque-speed curve was proportional to that given by Fig. 24 in a paper by A. L. Nelson entitled Fuel Problem in Relation to Engineering Viewpoint, published in THE JOURNAL for February, 1921; 32-in. tires; a rear-axle ratio of 4.42 to 1; a car-weight of 3096 lb. without any load and a passenger weight of 750 lb.

[19] Projected frontal area of car 26 sq. ft. The division of the total car resistance by the car-weight does not mean that the air-resistance varies with the car-weight. It was done for ease of comparison with the available thrust and road-resistance for 1000 lb. of car-weight.

[20] Ten pounds tractive force per 1000 lb. of car-weight is nearly equivalent to the tractive force required to move 1000 lb. up a 1-per cent grade.

the rear-wheel rims from fuel supplied the engine may be divided into four main groups; (*a*) the preparation of an explosive mixture of fuel and air, (*b*) the transformation of the chemical energy latent in the explosive mixture into gas pressure, (*c*) the transformation of the gas pressure produced into crankshaft torque and (*d*) the transformation of crankshaft torque to thrust at the road surface. The division lines between the first three items are not definite and can be drawn in several ways. In this paper the transformation of chemical energy into gas pressure is considered as starting with the passage of the spark through the explosive charge and terminating with the ceasing of combustion.

The preparation of an explosive mixture of air and fuel involves three major factors; (*a*) proportioning the proper weight of air to a given quantity of fuel, (*b*) mixing the fuel and air as intimately as possible, and (*c*) controlling the weight of combustible mixture used in a unit of time.

In proportioning the air and fuel it is important to know the limiting values of the ratios of weight of air to weight of fuel which will explode under cylinder conditions. There are some data available on this subject but they are inadequate. The results of some of the experiments made in 1915 by the Bureau of Mines[21] on the explosive range of mixtures of air and gasoline vapor are given in Table 9. The gasoline had an end-point of 140 deg. cent. (284 deg. fahr.) and its specific gravity at 15 deg. cent. (59 deg. fahr.) was 0.689 or 73.2 deg. Baumé. The mixture ratio[22] or the number of pounds of air per pound of gasoline was 27 to 34 for the lean explosive limit[23] and 6 to 7 for the rich explosive limit. Burgess and Wheeler[24] have measured the lower limit of inflammation of methane, ethane, propane, butane and pentane at atmospheric pressure and temperature. Their results show that the leanest explosive-mixture ratio varies from 29 for methane to 27 for pentane. Burrell and Robertson have found that up to 5 atmospheres an increase in initial pressure of an explosive mixture of methane and air has no effect on the lean explosive-mixture limit. They also report that it has been found in France that in the case of hydrogen-air mixtures an initial pressure of 40 atmospheres has no effect in changing the lower limit of inflammability. The same authors have shown that an increase in initial temperature from 23 to 500 deg. cent. (73 to 932 deg. fahr.) increases the possible leanness of the explosive mixture about 30 per cent. It is probable that heavier members of the parafin series follow the same general laws as methane. Indefiniteness is introduced into all measurements made on explosive range by the changing rate of inflammation with various mixture ratios.

The results of these measurements on explosive-mixture range are not directly applicable to internal-combustion-engine conditions for two reasons. First, the effect of heat losses, method of ignition and turbulence have a marked effect on the results in small glass bombs and these factors are very different in sealed glass bombs and in engine cylinders. Second, in an engine cylinder the explosive charge is diluted by the products of combustion from the previous working stroke. At the end of the exhaust stroke there remains in the clearance volume an almost constant weight of exhaust gas irrespective of the engine speed and load. As the weight of unburned charge taken in decreases with any decrease in the load, the percentage of exhaust-gas dilution increases. The effect of inert-gas dilution on explosive range of gasoline-air mixtures has not been extensively investigated. Fig 1 is drawn from admittedly meager data on this subject. It indicates that the less the stratification or the greater the turbulence of the cylinder contents, the richer the leanest mixture which will fire regularly must be. From the viewpoint of fuel economy, the lean explosive limit of the mixture of air, fuel and exhaust gases in the cylinder at ignition sets a maximum limit of leanness

TABLE 9—EXPLOSIVE RANGE OF MIXTURES OF GASOLINE VAPOR AND AIR

Initial Temperature, deg. cent.	Initial Temperature, deg. fahr.	Lean Explosive Limit
23	73	23 to 25
200	392	25 to 27
300	572	30 to 31
400	752	31 to 37

[21] See Bureau of Mines Technical Paper No. 115 entitled Inflammability of Mixtures of Gasoline Vapor and Air by G. A. Burrell and H. T. Boyd.

[22] The original data are given in percentages of gasoline vapor. The mixture ratios were computed from the experimental results on the assumption that the mixture giving a maximum of carbon dioxide on carburetion was an average chemical combining ratio of the paraffin series of 5.0.

[23] The lean explosive limit of a mixture of air and gasoline vapor from 50 to 60 deg. Baumé gasoline was found to be about 25.

[24] See Lower Limit of Inflammation of the Parafin Hydrocarbons in Air, published in the *Journal of the Chemical Society* (England), vol. 99, p. 2015.

and, therefore, thermal efficiency unless charge "stratification" is resorted to.

Within the explosive proportion limits there are two mixture proportions which are interesting from the point of view of internal-combustion engines and one from an academic viewpoint. These are (*a*) maximum economy mixtures, (*b*) maximum power mixtures and (*c*) chemically "correct" mixtures. Excellent experimental work has been done by several observers on maximum-economy mixtures and it is concluded that the mixture for maximum economy is the leanest mixture on which the engine will fire regularly,[25] usually about 16 to 1. Mixture ratios for maximum-power development have also been carefully studied,[26] and found to be practically independent of speed and load and to vary from 11 to 1 to 13 to 1.

The chemical combining ratios of about 40 compounds of four of the principal series of hydrocarbons found in automotive-engine fuels are given in Table 10. The

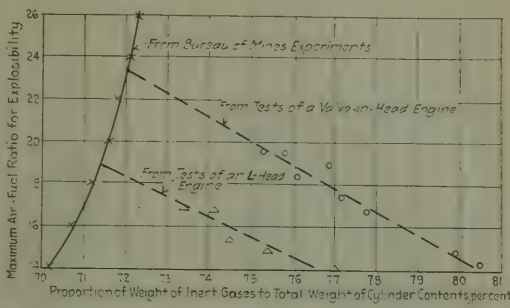
From Bureau of Mines Experiments
From Tests of a Valve-in-Head Engine
From Tests of an L-Head Engine
Maximum Air-Fuel Ratio for Explosibility
Proportion of Weight of Inert Gases to Total Weight of Cylinder Contents, per cent

FIG. 1—EFFECT OF AN INCREASE IN THE WEIGHT OF THE INERT GASES ON THE MAXIMUM AIR-FUEL RATIO FOR EXPLOSIBILITY

[25] See Appendix 1 to this paper.

[26] See Mixture Requirements of Automobile Engines by O. C. Berry, published in THE JOURNAL, November, 1919, p. 364, and Carburetion Requirements of a Typical Gas Engine by P. S. Tice, published in *Automotive Industries*, June 24, 1920, p. 1452.

TABLE 10—PROPERTIES OF HYDROCARBON COMPOUNDS FOUND IN ENGINE FUELS

Compound	Boiling Point at Atmospheric Pressure, deg. cent.	deg. fahr.	Chemical Combining Ratio of Air and Fuel	Vapor Volume, cu. ft. per lb.	Heating Value B.t.u. per lb.[27]	B.t.u. per cu. in.[28]
			Parafin Series			
C_5H_{12}	36.3	97.3	15.24	4.98	.....	.....
C_6H_{14}	69.0	156.2	15.15	4.17	19,360	0.0545
C_7H_{16}	98.4	209.1	15.09	3.58	19,260	0.0545
C_8H_{18}	125.5	257.9	15.03	3.14	19,180	0.0547
C_9H_{20}	150.0	302.0	15.00	2.80	.....	.....
$C_{10}H_{22}$	173.0	343.4	14.97	2.52	.....	.....
$C_{11}H_{24}$	195.0	383.0	14.95	2.30	.....	.....
$C_{12}H_{26}$	214.0	417.2	14.93	2.11	.....	.....
$C_{13}H_{28}$	234.0	453.2	14.91	1.95	.....	.....
$C_{14}H_{30}$	252.0	485.6	14.89	1.81	.....	.....
$C_{15}H_{32}$	270.0	518.0	14.88	1.69	.....	.....
			Aromatic Series			
C_6H_6	80.2	176.4	13.19	4.60	17,360	0.0558
C_7H_8	110.3	231.1	13.43	3.90	17,580	0.0558
C_8H_{10}	140.0	284.0	13.60	3.39	17,720	0.0557
C_9H_{12}	....	....	13.72	2.99	.....	.....
$C_{10}H_{14}$	....	....	13.82	2.68	.....	.....
$C_{11}H_{14}$	....	....	13.90	2.42	.....	.....
$C_{12}H_{16}$	....	....	13.98	2.22		
$C_{13}H_{18}$	....	....	14.03	2.04		
$C_{14}H_{22}$	....	....	14.08	1.89		
$C_{15}H_{24}$	....	....	14.13	1.76		
			Olefin Series			
C_5H_{10}	36	96.8	14.69	5.12		
C_6H_{12}	69	156.2	14.69	4.27		
C_7H_{14}	96-99	204.8-210.2	14.69	3.66		
C_8H_{16}	122-123	251.6-253.4	14.69	3.20		
C_9H_{18}	140-142	284-287.6	14.69	2.84		
$C_{10}H_{20}$	175	347.0	14.69	2.56		
$C_{11}H_{22}$	196-197	384.8-386.6	14.69	2.33		
$C_{12}H_{24}$	212-214	413.6-417.2	14.69	2.13		
$C_{13}H_{26}$	233	451.4	14.69	1.97		
$C_{14}H_{28}$	...	....	14.69	1.83		
$C_{15}H_{30}$	247	476.6	14.69	1.71		
			Acetylene Series			
C_5H_8	48-50	118.4-122.0	14.12	5.27		
C_6H_{10}	68-70	154.4-158.0	14.23	4.37		
C_7H_{12}	100-101	212.0-213.8	14.29	3.74		
C_8H_{14}	133-134	271.4-273.2	14.34	3.26		
C_9H_{16}	....	....	14.38	2.89		
$C_{10}H_{18}$	....	....	14.41	2.60		
$C_{11}H_{20}$	210-215	410.0-419.0	14.44	2.36		
$C_{12}H_{22}$	....	....	14.46	2.16		
$C_{13}H_{24}$	....	....	14.48	1.99		
$C_{14}H_{26}$	....	....	14.50	1.85		
$C_{15}H_{28}$	....	....	14.51	1.72		

[27] See Character of Various Fuels for Internal-Combustion Engines by H. T. Tizard and D. R. Pye, published in *The Automobile Engineer*, February, 1921, p. 55.

[28] These values are per cubic inch of mixture at a pressure of 760 mm. (29.92 in.) of mercury and a temperature of 20 deg. cent. (68 deg. fahr.).

TABLE 11—AVERAGE MIXTURE RATIO USED BY 23 CARS UNDER WINTER CONDITIONS.

Condition of Test	Mixture Ratio
Engine Racing	11.9
Engine Idling	12.5
Up 3-Per Cent Grade at 15 m.p.h.	12.5
Up 3-Per Cent Grade at 10 m.p.h.	12.2
Up 3-Per Cent Grade at 3 m.p.h.	12.0
On Level at 15 m.p.h.	12.9
On Level at 10 m.p.h.	12.8
On Level at 3 m.p.h.	12.7
Down 3-Per Cent Grade at 15 m.p.h.	12.8
Down 3-Per Cent Grade at 10 m.p.h.	13.0
Down 3-Per Cent Grade at 3 m.p.h.	13.5

figures show that were equal proportions of each of the 10 compounds of the parafin series mixed in a single fuel the chemically correct mixture-ratio of the average would be incorrect for the lightest or heaviest component by only 1.2 per cent. Similarly such a mixture for the aromatics would be incorrect by 3.5 per cent, for the acetylenes 1.3 per cent and always correct for the olefines.

It will be noticed that the maximum-economy mixtures are leaner and the maximum-power mixtures are richer than the chemically correct mixtures. The presence of exhaust gases, the law of mass action and the limited time available for the completion of the reaction would explain why all three mixtures are not the same. At the present time our knowledge of the relations between these factors is insufficient. In a cylinder of fixed dimensions, as the oxygen occupies a greater volume than the fuel vapor it must be entirely consumed to obtain the maximum power. To accomplish this in the shortest possible time an excess of vapor must be present. In the same way when all the fuel is to be consumed as in the case of maximum economy mixtures, an excess of air must be present.

To indicate what the variation in the mixture ratio with changes in the speed and the load is with present carbureters, several makes of stock carbureters, representing at least 60 per cent of the total number of carbureters in use today, have been tested in the carbureter test-plant at the Bureau of Standards. The results which are presented in Appendix 2 show that there is little agreement among carbureter manufacturers as to the variation of mixture-ratio requirements with changing loads and speeds.

Table 11 gives the average mixture-ratio supplied the engines of 23 average cars tested under winter conditions by the Bureau of Mines.[29] The mixture-ratios were computed from exhaust-gas analysis and indicate that, on the average, cars under winter conditions are using a mixture-ratio ranging from 12 to 13.5, corresponding more nearly to maximum power than maximum economy.

Mixing and Vaporization

Insufficient fuel and air mixing is probably the source of the greatest fuel waste today. Poor distribution among cylinders and the need for over-rich mixtures when starting and accelerations are the result of insufficient mixing. Minute and thorough subdivision of the fuel is the solution of the mixing problem. The difficulties involved in attaining thorough mixing are realized when it is appreciated that (*a*) when liquid gasoline is injected into an airstream probably not more than a small percentage is ever vaporized before entering the engine cylinder except when the air in the manifold is heated; (*b*) a cube of liquid gasoline 0.1 in. on a side is all that is required to be mixed with a cube of air 2.1 in. on a side; (*c*) when the cube of gasoline is evaporated the vapor occupies a cube 0.6 in. on a side; and (*d*) from 0.1 to 1.0 sec. elapses from the time the liquid fuel leaves the carbureter jet until it is ignited within the cylinder (See Figs. 2 and 3). Subdivision of the fuel may be accomplished in two ways, (*a*) by vaporization or change in state, and (*b*) by minute subdivision of the liquid or atomization.

Vaporization of the liquid fuel gives the most minute subdivision attainable. To vaporize the fuel a definite quantity of heat must be supplied per pound. Table 12 gives a number of values for the latent heat of vaporization and specific heats of the liquid for gasolines and some pure compounds found in liquid fuels. Variation in the latent heat values are to be expected from the known variation in the composition of gasolines. Vapor-

TABLE 12—LATENT HEATS OF VAPORIZATION

Fuel	Latent Heat of Evaporation, B.t.u. per lb.	Authority
Gasolines		
Aromatic free	133.0	Ricardo
"A"	142.0	Ricardo
"B"	140.0	Ricardo
"C"	135.0	Ricardo
"D"	132.0	Ricardo
"E"	133.0	Ricardo
"F"	134.0	Ricardo
"H"	145.0	Ricardo
Gasoline	100.2	Redwood
Heavy Fuels		
Heavy Aromatic	136.0	Ricardo
Kerosene	108.0	Ricardo
Kerosene	105.4	Redwood
Parafin Series		
Hexane, 80 per cent	156.0	Ricardo
Hexane	210.0	Sorell
Heptane, 97 per cent	133.0	Ricardo
Decane at 159.45 deg. cent. (318.65 deg. fahr.)	109.5	Longuinine
Aromatic Series		
Benzene, pure	172.0	Ricardo
Benzol	169.0	Marks' Handbook
Benzol at 0 deg. cent. (32 deg. fahr.)	196.0	Regnault
Benzol at 100 deg. cent. (212 deg. fahr.)	238.0	Regnault
Benzol at 210 deg. cent. (410 deg. fahr.)	278.0	Regnault
Toluene, 99 per cent	151.0	Ricardo
Xylene, 91 per cent	145.0	Ricardo
Naphthene Series		
Cyclohexane, 93 per cent	156.0	Ricardo
Hexahydrotoluene, 80 per cent	138.0	Ricardo
Hexahydroxylene, 60 per cent	133.0	Ricardo
Alcohol Group		
Ethyl Alcohol, 98 per cent	406.0	Ricardo
Ethyl Alcohol at 78 deg. cent. (172 deg. fahr.)	372.0	Schall
Methyl Alcohol at 64.5 deg. cent. (148 deg. fahr.)	482.0	Wirtz
Acetone	239.0	Ricardo
Acetone	233.0	Marks' Handbook
Acetone at 20 deg. cent. (68 deg. fahr.)	247.0	Regnault
Miscellaneous		
Carbon Bisulphide 50 per cent Aromatic free 50 per cent by volume	145.0	Ricardo

[29] See Gasoline Losses Due to Incomplete Combustion in Motor Vehicles by A. C. Fieldner, A. A. Straub and G. W. Jones, published in *Journal of Industrial and Engineering Chemistry*, vol. 13, p. 51.

ized fuel occupies over 200 times the volume of the liquid fuel before vaporization, and in an explosive mixture the vapor volume represents from 1 to 2.5 per cent of the total volume of the charge. Table 10 gives the vapor volumes of some compounds.

Complete vaporization of the fuel would decrease the volume of air which could be admitted to a fixed cylinder; hence, the power of the engine by about 2 per cent. On the other hand, the cooling of the charge caused by such evaporation, if no heat were supplied the air from external sources, would contract the air by some 7 per cent, thus increasing the power output by this amount. Thus vaporization of the fuel causes a net increase in the power output, and the heating of the charge in the manifold, a decrease. The temperature required for complete vaporization is at least equal to the temperature at which the vapor pressure of the fuel equals its partial pressure in the explosive mixture. If this is more than about 20 deg. fahr. above that of the entering air, a net loss of air volume will result.

Sufficiently fine atomization of the liquid fuel at the carbureter jet and subsequent vaporization within the cylinder during compression would accomplish the same result as vaporization without the attendant loss of air volume and hence power output. Very little information is available as to the formation of minute liquid particles from a solid liquid stream, but very suggestive reading can be found in the article on Capillary Action by James Clerk Maxwell and Lord Rayleigh in the 11th Edition of the Encyclopedia Britannica. There have been no methods for the measurement of the size of particles applied to the discharge from carbureters and no quantitative data are available on the subject.

Charge Quantity Control

Three methods have been used to control the quantity of explosive charge used, namely, reducing (*a*) the manifold pressure but not the volume of the charge drawn from it which is the usual throttle control; (*b*) the effective time-interval of inlet-valve opening, but not the manifold pressure or what is known as variable inlet-valve timing; and (*c*) the weight of the *combustible* charge but not the cylinder charge weight or the stratification and direct fuel-injection method. In the first method the power required to pump the cylinder charge from the manifold to the exhaust pressure increases with a reduced load, thus reducing the economy with the load. At 20 per cent full load the loss in economy may amount to about 20 per cent.[30] Exhaust-gas dilution also increases with a reduction in the load and thus reduces the leanness of the mixtures which will explode. When variable inlet-valve timing is used there is no increase in the "pumping loss" with a reduction in the load, and the exhaust-gas dilution increases with a reduction in the load in the same manner as when charge throttling is used. However, mechanical complications are introduced. Results on a test of an engine using a late-closing inlet-valve[31] show that at a little less than half-load the fuel-consumption was about 50 per cent less than that attained when using fixed valve-timing and the usual throttle control. In the case where charge stratification is relied on entirely, "pumping loss" is entirely eliminated. As yet no commercial application of direct-injection engines has been made to automobiles. Mr. Ricardo[32] also gives results from tests of an engine using stratified charge and fuel throttling for reduced loads. The results show a remarkably constant thermal efficiency of from 30 to 35 per cent from full load to about 0.15 load.

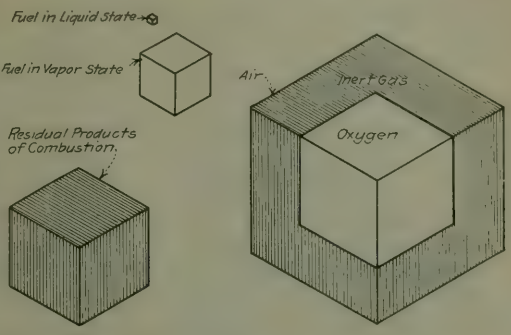

Fig. 2—Relative Volume of Gases in the Engine Cylinder at Full Load

The chemical energy of the explosive mixture supplied the cylinder is transformed into gas pressure by (*a*) an increase in temperature of the gases within the cylinder resulting from heat added during combustion and (*b*) a difference in specific volume of the gases before and after combustion, due to a change in the number of molecules during combustion. Except in the case of Diesel engines which will not be considered here, combustion is usually started by the passage of an electric spark through the explosive mixture. Detailed information on ignition properties will be found in the following papers:

J. D. Morgan—Principles of Electric-Spark Ignition in Internal-Combustion Engines, published by Crosby Lockwood & Co.
An excellent general discussion of the subject

C. C. Paterson and N. R. Campbell—Some Characteristics of the Spark Discharge and Its Effects in Igniting Explosive Mixtures, published in *Proceedings of the Physical Society* (London) vol. 31, p. 168
A detailed account of researches at National Physical Laboratory

A. P. Young and H. Warren—The Process of Ignition, *Automobile Engineer*, March, 1920, p. 115

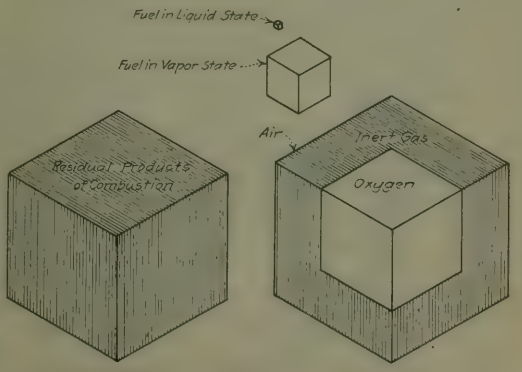

Fig. 3—Relative Volume of Gases in the Engine Cylinder at a 20-Per Cent Load

[30] See Appendix 3 to this paper.

[31] See Some Possible Lines of Development in Aircraft Engines by H. R. Ricardo, published in *Aeronautical Journal* (London), March, 1921, p. 143.

[32] See *Aeronautical Journal* (London), March, 1921, p. 140.

A general discussion from the engineer's point of view, with many data on sparking voltages

W. S. Gorton—The Subsidiary Gap as a Means for Improving Ignition. Report No. 57 of the Fourth Annual Report of the National Advisory Committee for Aeronautics

This discusses the operation of the so-called spark intensifiers

F. B. Silsbee—Ignition Work at the Bureau of Standards. *Automotive Industries*, June 12, 1919, p. 1294, and the Fifth Annual Report of the National Advisory Committee for Aeronautics

The voltage necessary to produce this spark varies from about 2000 to 15,000 volts,[33] increasing with increase in density of the charge and length of spark-gap at constant temperatures of the electrodes. Recently it has been found that an increase in the temperature of the spark-plug electrodes decreases materially the sparking voltage required. This decrease may amount to as much as 50 per cent. It has been shown[34] that when a truly explosive charge surrounds the spark-gap any spark passing the gap will ignite the charge. It has not been shown, however, that this is true if the explosive charge be near the limit of inflammability, from either incomplete vaporization or dilution. The results of the experiments on the explosive limits of mixtures indicate that the character of the spark discharge has a decided effect on ignition. The effect of spark characteristics on the ignition of poor mixtures needs further attention.

Mention should be made of "spontaneous" or "auto-ignition" temperatures. Spontaneous-ignition temperature is usually thought of as the temperature at which a given mixture ignites without ignition being supplied at any point from an outside source. Spontaneous ignition may occur in an engine cylinder with certain fuels and compression-ratios. When an engine is operating certain metal parts, such as spark-plug electrodes and valves, or carbon deposits, remain at a higher temperature than the average temperature of the charge. If the temperature of any of these surfaces is sufficiently above the ignition point of the fuel so that it can supply enough heat to raise a portion of the charge to the spontaneous-ignition temperature, ignition will take place even though the average temperature of the gas is below its spontaneous-ignition temperature. The lower the ignition temperature of the gas, the smaller the rise in temperature necessary to be produced in this way. Hence, ignition of this sort will occur in the engine at average mixture temperatures lower than the spontaneous-ignition temperatures of the fuel, but these average mixture temperatures will vary under the same cylinder conditions with different fuels in much the same manner as the true spontaneous-ignition temperatures of the fuels. It has been shown[35] that the spontaneous-ignition temperature for hydrogen at least is materially raised by the dilution of the explosive mixture by an inert gas. Some values for spontaneous-ignition temperatures are given in Table 13.

Assuming the usual pressure-volume and temperature relations, the increase in the average gas temperature and therefore the cylinder pressure is limited by four factors, (*a*) the amount of heat liberated by the combustion of the fuel per unit volume of combustible mixture, allowing for heat absorbed in the dissociation of the products of the combustion, (*b*) the heat capacity of the gases contained in the cylinder at the end of the preceding exhaust stroke, (*c*) the rate of heat loss from the hot gases, and (*d*) the rate at which the mixture burns.

Heat of Combustion

The heats of combustion of nearly all of the constituents of gasoline have been measured. Some values for these heats of combustion are given in Table 10 in terms of British thermal units per pound of fuel and British thermal units per cubic inch of combustible mixture of several mixture strengths. The effects of dissociation on the effective heats of combustion will not be considered here, although it is of great importance in determining the effective heating value of the fuel. An excellent treatment by Tizard and Pye has been published recently in *The Automobile Engineer*.[36]

There is considerable doubt as to the accuracy of the available specific heat measurements of gases at high

[33] See Report No. 54 of the Fifth Annual Report of the National Advisory Committee for Aeronautics and Process of Ignition by A. P. Warren and H. Young, published in *The Automobile Engineer*, March, 1920, p. 115.

[34] See Some Characteristics of the Spark Discharge and Its Effects in Igniting Explosive Mixtures by C. C. Paterson and N. R. Campbell, published in *Proceedings of the Physical Society* (London), vol. 31, p. 168.

[35] See Ignition Temperatures of Gaseous Mixtures by K. G. Falk, published in *Journal of the American Chemical Society*, vol. 29, p. 1536.

[36] See Character of Various Fuels for Internal-Combustion Engines by H. T. Tizard and D. R. Pye, published in *The Automobile Engineer*, February, 1921, p. 55, March, 1921, p. 98, and April, 1921, p. 134, and Specific Heat of the Working Fluid in Internal-Combustion Engines by D. R. Pye, published in *The Automobile Engineer*, February, 1920, p. 57.

TABLE 13—SPONTANEOUS-IGNITION TEMPERATURES

Fuel	Ignition Temperature In Oxygen deg. cent.	In Oxygen deg. fahr.	In Air deg. cent.	In Air deg. fahr.	Authority
Gasoline, Anglo-American Oil Co., Ltd.	...	...	392	738	Moore
Kerosene, Anglo-American Oil Co., Ltd.	...	...	367	693	Moore
Xylol, Commercial	484	893	...	...	Moore
Toluol, 90 per cent	516	961	...	...	Moore
Benzol, 100 per cent	566	1051	...	...	Moore
Ethyl Alcohol	395	743	518	964	Moore
Alcohol	510-515	950-959	595-600	1103-1112	Dixon
Ether, Methylated	190	374	347	657	Moore
Ether	235-240	455-464	560-580	1040-1076	Dixon
Carbon Bisulphide	119	246	...	...	Moore
Nitrobenzene	432	810	...	...	Moore
Anilene	550	1022	...	...	Moore
Benzene, Crystallisable	620	1148	...	...	Moore
Pure Toluene	596	1109	...	...	Moore
Normal Hexane	287	549	...	...	Moore
Heptane	281	538	...	...	Moore
Pentane	550	1022	560-570	1040-1058	Dixon

TABLE 14—SPECIFIC HEATS AT A CONSTANT VOLUME OF SOME GASES USED AS THE WORKING FLUID IN INTERNAL COMBUSTION ENGINES[27]

Temperature Range deg. cent.	Temperature Range deg. fahr.	Gases: Carbon Dioxide	Gases: Nitrogen	Gases: Water Vapor	Authority
0	32	0.152	0.178	0.352	Holborn, Scheel and Henning
0- 200	32- 392	0.174	0.180	0.361	Holborn, Scheel and Henning
0- 400	32- 752	0.189	0.182	0.366	Holborn, Scheel and Henning
100- 500	212- 932	0.188	0.192	0.348	Tizard and Pye
0- 600	32-1,112	0.200	0.184	0.375	Holborn, Scheel and Henning
0- 800	32-1,472	0.207	0.186	0.384	Holborn, Scheel and Henning
0-1,000	32-1,832	0.212	0.188	0.394	Holborn, Scheel and Henning
100-1,000	212-1,832	0.217	0.196	0.386	Tizard and Pye
0-1,200	32-2,192	0.217	0.190	0.403	Holborn, Scheel and Henning
0-1,400	32-2,552	0.224	0.192	0.412	Holborn, Scheel and Henning
100-1,500	212-2,732	0.229	0.204	0.425	Tizard and Pye
100-2,000	212-3,632	0.238	0.213	0.468	Tizard and Pye
100-2,500	212-4,532	0.247	0.222	0.539	Tizard and Pye
100-3,000	212-5,432	0.249	0.234	0.623	Tizard and Pye

AVERAGE VALUES BETWEEN 20 AND 100 DEG. CENT. (68 AND 212 DEG. FAHR.) FOR AIR ACCORDING TO HOLBORN, SCHEEL AND HENNING

Pressure, lb. per sq. in.	Specific Heat at a Constant Volume
14.7	0.172
200.0	0.176
400.0	0.180
600.0	0.184
800.0	0.188
1,000.0	0.192
1,200.0	0.196
1,400.0	0.200

[27] The figures given are average values for the range stated. The values attributed to Tizard and Pye are taken from an article by them entitled Character of Various Fuels for Internal-Combustion Engines which was published in *The Automobile Engineer*, February, 1921, p. 56; the others are from Wärmetabellen by L. Holborn, K. Scheel and F. Henning.

temperatures and pressures. Tizard and Pye, who have examined the experimental results with care, believe the values obtained by Pier and Bjerrum are very good. The values quoted by them are given in Table 14, together with values obtained by Holborn and Henning. It will be noted that the results quoted show a decided increase in specific heat with increase in temperature and pressure.

The rate of heat loss from the gases during combustion to the cylinder walls is not known. It is probably very high but of short duration. Measurements of the amount of heat entering the jacket water are of little value for this purpose. There is very little reliable information on the rate at which energy is liberated from a combustible mixture. This rate is not necessarily that with which the flame passes through a mixture. Some idea of the rate of heat liberation during combustion can be gained from Fig. 4. The data presented in this plot were obtained with the high-speed indicator developed at the Bureau of Standards and published values of specific heat. It indicates what variations in the rate of burning are to be expected.

The number of factors believed to affect the rate of burning is large, probably because we know so little about it and cannot as yet separate the important from the unimportant factors. Some of these will be enumerated but not discussed because of lack of information. They are (*a*) temperature and pressure at ignition, (*b*) point of stroke at which ignition occurs,[28] (*c*) number of points of ignition, (*d*) mixture ratio, (*e*) shape of combustion-chamber, (*f*) fuel, (*g*) turbulence, (*h*) auto-ignition temperature of fuel and (*i*) detonation tendency. The phenomena related to what is usually termed "detonation" and probably more fittingly termed by Dr. Gibson "flame slap" are discussed in Appendix 5.

The ratio of the volume of the charge after combustion to the volume before combustion at the same temperature and pressure is given for about 10 of each of the principal series of compounds occurring in engine fuels in Table 10. The cylinder pressures after combustion will be increased by an amount proportional to the increase

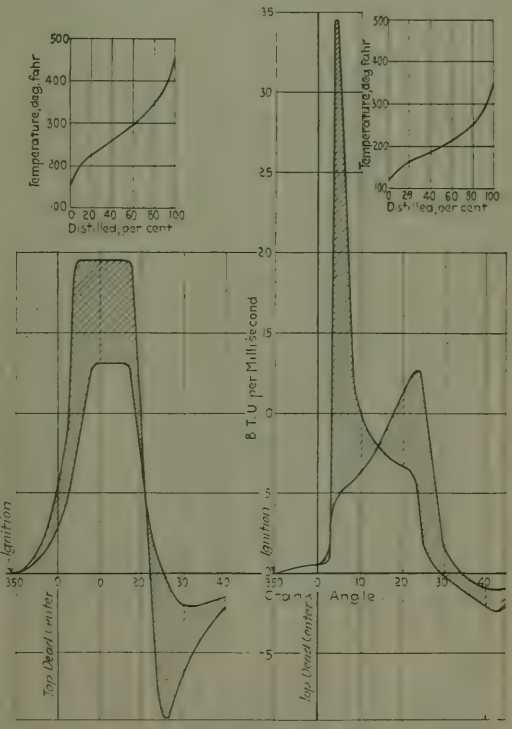

FIG. 4—CURVE SHOWING THE RATE OF HEAT LIBERATION DURING COMBUSTION

[28] See Recent Automobile Research at the Bureau of Standards by Herbert Chase, published in *Automotive Industries*, April 7, 1921, p. 759.

TABLE 15—TESTS OF A FRANKLIN TRANSMISSION ON DIRECT DRIVE

Speed, r.p.m.	Power Input, b.hp.	Efficiency, per cent.
800	1	80.0
800	2	85.0
800	4	95.0
800	6	97.0
800	16	97.0
1,200	2	84.0
1,200	4	92.0
1,200	6	95.0
1,200	8	96.0
1,200	10	97.0
1,200	14	98.0
1,200	18	98.0
1,500	2	80.0
1,500	4	89.0
1,500	6	93.0
1,500	8	95.0
1,500	14	97.0
1,500	18	97.5

in specific volume given in the table. This increase in pressure due to the presence of a greater number of molecules increases with the molecular weight of the fuel.

Gas Pressure Transformation Loss

The transformation of gas pressures into crankshaft torque in a cylinder, reciprocating piston and crank mechanism is fundamentally an intermittent process. It is made continuous either by the use of a reservoir of energy such as a flywheel or by the multiplication of elements acting intermittently, that is, the addition of working cylinders. There are four sources of loss in this mechanism: (*a*) incomplete expansion, (*b*) heat transfer from the gases under pressure, (*c*) work of filling and exhausting the cylinder and (*d*) mechanical friction of the moving parts. The loss from incomplete expansion is usually given in terms of air as a working fluid and is one minus the so-called air-cycle efficiency. The usual computation of the air-cycle efficiency involves the assumptions that (*a*) the last three sources of loss mentioned earlier in this paragraph are zero, (*b*) the combustion is instantaneous, (*c*) the specific heat at constant volume is independent of both temperature and pressure, (*d*) the specific volume of the working fluid after combustion is the same as it is before combustion, (*e*) the ratio of specific heats of the unburned charge is the same as that for the burned charge and both are independent of temperature and pressure and (*f*) there is no dissociation of the products of combustion. Any loss incurred through incomplete expansion is directly due to the imperfection of the mechanism, because it is impracticable to increase the expansion without an excessive increase in the weight and size of the engine. This loss however should not be altered by the losses or gains resulting from the last five assumptions just made, nor should it be altered by assuming constants for a working fluid other than that which it is actually possible to use. Losses or gains due to these assumptions should be charged to the fuel and working fluid used. To be sure, our present knowledge of the effect of these assumptions is incomplete but it is sufficient to tell us that none of them is negligible. The relationships involved in each can and should be determined in order that the status of any process of combustion under pressure can be truly interpreted. Some recent preliminary determinations of the ratio of specific heats at atmospheric temperature and pressure of a particular sample of explosive mixture taken from an engine, gave a value of 1.36 and a particular sample of exhaust gas gave 1.34. Corrections for the higher temperatures of the exhaust gases would probably reduce the latter figure below 1.30.

The loss due to the heat transferred from the working fluid to the cylinder walls is directly chargeable to the type of mechanism used. No good values of this loss have been determined but they may range from 15 to 25 per cent of the total heat in the fuel. The work lost in filling and exhausting the cylinder includes (*a*) a direct loss, negative piston-pressures as given by the lower loop of the indicator card, and (*b*) an indirect loss, the loss in the weight of the cylinder charge due to throttling, gas heating, etc., usually included under the term volumetric efficiency, which is one of the factors governing the size of the engine used to give a definite performance, or the maximum power output of a given engine. Any reduction in the maximum power with a constant mechanical loss involves a loss in brake efficiency, and if a larger engine is required to produce the same power, both the mechanical losses and the power required to carry the engine are increased as the size of the engine is increased. The losses due to negative piston-pressures increase with reduction in load and their magnitude is indicated in Appendix 3. Losses due to a reduction of the cylinder charge vary with valve-timing, valve design and engine speed. They may vary from 50 to less than 5 per cent. The losses due to mechanical friction of the moving parts vary from 10 to 40 per cent with different engines and increase so materially with speed as to raise some doubt as to the possible fuel-economy of small high-speed engines. (See Appendices 3 and 6.)

The transformation of crankshaft torque into thrust at the rear wheels involves three factors; (*a*) transmission efficiency, (*b*) universal-joint efficiency, and (*c*) rear-end efficiency. All of these factors are affected to a marked degree by the kind of lubricant used and its method of application.

Power Transmission Efficiency

Considering the system as a unit the efficiencies may vary from 50 to 85 per cent according to Riedler.[39] The value given by the Automobile Engineer's Handbook, 1920, London, is 85 per cent. Lewis P. Kalb[40] considers 90 per cent to be a closer value. Universal-joint efficiencies according to C. W. Spicer[41] range from about 92 to nearly 100 per cent when transmitting power in excess of 5 hp. At lower powers the efficiency may drop as low as 80 per cent. These data include results with angles of from 2 to 12 deg. with forks in the same plane and at 90 deg. Mr. Spicer makes the following statement:

> Between 10 and 100 per cent of full load, the efficiency is above 99 per cent for all angles less than 7 deg.

The efficiency of the gearbox according to tests made by Worby Beaumont is from 70 to 90 per cent on direct drive. Tests of a Franklin transmission described in *The Horseless Age*[42] give the results contained in Table 15 on direct drive. C. M. Allen[43] finds efficiency of a worm-gear axle varies from 70 to 85 per cent with power inputs of from 2 to 8 hp. reaching 90 per cent for higher inputs. With a bevel-gear axle the efficiencies ranged

[39] See Scientific Determination of the Merits of Automobiles by A. Riedler.

[40] See TRANSACTIONS, vol. 14, part 2, p. 69.

[41] See TRANSACTIONS, vol. 10, part 1, p. 247.

[42] See *Horseless Age*, Feb. 12, 1908, p. 161.

[43] See *Transactions of the American Society of Mechanical Engineers*, vol. 40, p. 101.

from 95 to 98 per cent with inputs of from 2 to 8 hp. and were above 98 per cent for higher inputs.

From the point of view of the power requirements of cars it is believed that (*a*) the car performance demanded by the average driver is not unreasonable and (*b*) greater fuel-economy could be attained by a sound far-sighted good-roads program through possible reduction of car-weight and also road-resistance.

From the point of view of power development and its delivery to the road it is believed that (*a*) the greatest gain in fuel-economy would result from an effort spent on the preparation of the unburned charge under all conditions of temperature, engine speed and load, first from a thorough mixing of the air and fuel and second from a correct variation of the fuel and air proportions; (*b*) the reduction of the mechanical friction losses, possibly through a change of engine speed and size, will increase the fuel-economy at part throttle without any sacrifice in performance and (*c*) the closer study of the processes of combustion will make possible a rational basis for the statement of the ultimate engine efficiency and a clearer conception of the value of different fuels.

APPENDIX 1.

Influence of Air and Fuel Proportions Upon Engine Efficiency and Power[44]

The carbureter exists to proportion air and fuel so that the engine can deliver its maximum power or attain its maximum efficiency. Experiments to determine what these proportions should be have been made usually upon multi-cylinder engines. Faulty distribution influences the results thus obtained since it necessitates an excess of fuel being supplied to some cylinders in order that the other cylinders can receive sufficient fuel for satisfactory operation. These results are, however, of immediate value as they show what proportions the carbureter must furnish to cope with the faults of existing induction systems and yet give satisfactory engine operation. Determining these proportions with a one-cylinder engine as has been done by Mr. Ricardo eliminates the distribution problem and results thus obtained fix values that can be approached by the multi-cylinder engine as its distribution improves.

The chemical combining proportion of air and a given fuel is a fixed quantity. In practice, a lower air-fuel ratio usually gives greater power and a higher air-fuel ratio greater economy. One reason for this is the lack of an intimate mixing of the air and the fuel. Excess fuel makes certain that all the oxygen of the air is brought into contact with sufficient fuel for combination and since the engine power is limited by the amount of air that can be utilized in a unit time this insures the attainment of the maximum power. Supplying excess air tends to make certain that all the fuel is intimately associated with sufficient air to insure its combustion and thus to attain the maximum economy. In the first case, the maximum output of the engine is desired and in the second case the maximum output from the energy of the fuel.

Investigators are in fairly close agreement as to the air-fuel proportions for maximum power, finding ratios of from 11 to 1 to 13 to 1 best in this regard for ordinary gasoline. A recent series of tests at the Bureau of Standards has shown that with an aviation engine having compression ratios of 5:3, 6:3, 7:3, and 8:3, the maximum power was obtained with air-fuel ratios of from 13 to

[44] Contributed by S. W. Sparrow, M.S.A.E.—Mechanical engineer, Bureau of Standards, Washington.

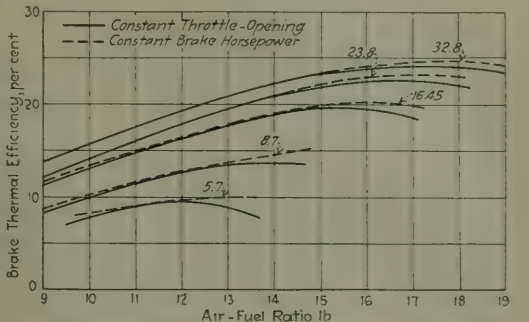

Fig. 5—Relation of Brake Thermal Efficiency to the Air-Fuel Ratio

1 and 14 to 1 with air densities of from 0.025 to 0.075 lb. per cu. ft. This was, however, with aviation gasoline, a more volatile product than the commercial fuel.

Maximum economy is the condition with which the automobile engineer is most concerned. It would therefore be expected that much reliable information would be

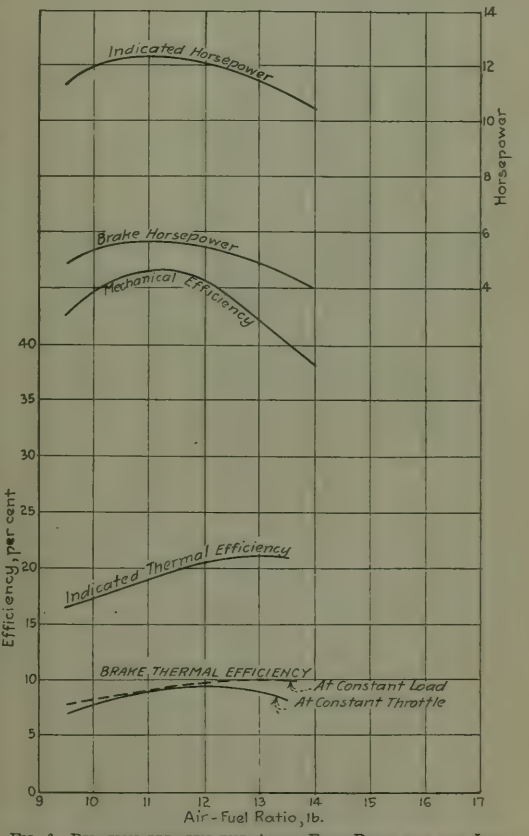

Fig. 6—Relation between the Air-to-Fuel Ratio and the Indicated and Brake Horsepowers and the Mechanical, Indicated Thermal and Brake Thermal Efficiencies

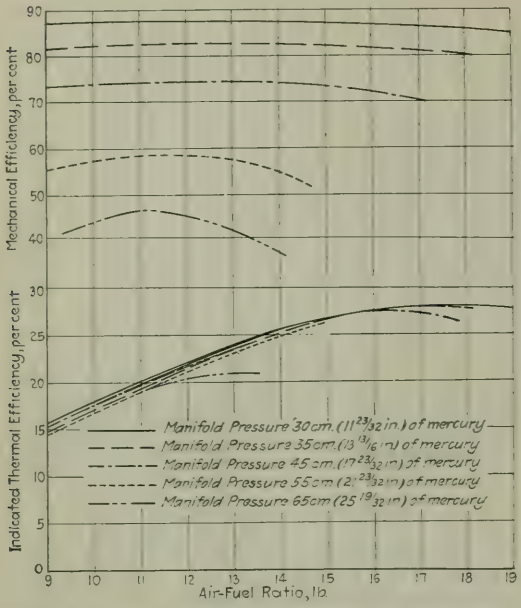
Mechanical Efficiency, per cent
Indicated Thermal Efficiency, per cent
Air-Fuel Ratio, lb
Manifold Pressure 30 cm. (11 23/32 in.) of mercury
Manifold Pressure 35 cm. (13 13/16 in.) of mercury
Manifold Pressure 45 cm. (17 23/32 in.) of mercury
Manifold Pressure 55 cm. (21 23/32 in.) of mercury
Manifold Pressure 65 cm. (25 19/32 in.) of mercury

FIG. 7—RELATION BETWEEN THE MECHANICAL AND INDICATED THERMAL EFFICIENCIES AND THE AIR-FUEL RATIO FOR DIFFERENT MANIFOLD DEPRESSIONS

available on this phase of the problem. On the contrary, the results of some of the most extensive investigations in this field seem to have been incorrectly analyzed and interpreted. Hence it is worthwhile to comment at some length on this error of interpretation to prevent its being made by others. In studying engine operation at reduced loads with various air-fuel ratios, the condition that was maintained constant has usually been the throttle position or the manifold pressure. Results are then plotted in a family of curves, such as are given in full lines in Fig. 5, which show the relation of brake thermal efficiency or fuel-consumption in pounds of fuel per brake horsepower-hour to air-fuel ratio. It will be noted that the highest efficiency shown by the upper full-line curve occurs with a mixture ratio of 17 to 1, while the highest shown by the lower full-line curve is at a mixture ratio of 12 to 1: As 33 b.hp. is obtained in one case and 6 in the other it is natural, but incorrect, to conclude that for maximum efficiency the air-fuel ratio should vary from 17 to 1 to 12 to 1 with this change in the brake horsepower. What is wrong? The curves show the mixture proportions that will give maximum efficiency at a constant throttle-opening. They do not show the mixture-ratio at which a *given power* can be developed at maximum efficiency, which is the information desired. Fig. 6 has been prepared to make this point clear. In addition to the efficiency at a constant throttle the brake horsepower is plotted. Adding to the latter the friction horsepower, which would not change appreciably with the change in the mixture-ratio, gives the indicated horsepower. Dividing the brake horsepower by the indicated horsepower gives the mechanical efficiency, and by dividing the brake thermal efficiency by the mechanical efficiency the indicated thermal efficiency is obtained. The last named efficiency is the percentage of the energy of the fuel that is converted into work and it is greatest with an air fuel ratio of 13.5 instead of 12, although higher efficiency would be obtained at a much leaner mixture if the engine would operate regularly on such a mixture. In developing a given brake horsepower the friction horsepower and hence the mechanical efficiency will be independent of mixture ratio. To maintain a constant brake horsepower with any change in the mixture proportions the throttle must be opened slightly for mixtures other than those giving the maximum power. The magnitude of this effect is too small to be considered here but neglecting it makes the proportions chosen for the maximum efficiency somewhat richer than the correct ones. Hence multiplying the indicated thermal efficiency by the constant mechanical efficiency for a given brake horsepower, gives the brake thermal efficiency obtained with various air-fuel ratios when developing this power. The dotted line shows the result obtained in this instance.

In the manner just described, the mechanical and indicated thermal efficiencies for all the conditions of Fig. 5 have been plotted in Fig. 7. From these values the dotted curves of Fig. 5, giving the brake thermal efficiencies at a constant power, have been derived. It will be obvious from the foregoing that for a *given power development* at less than full throttle the maximum indicated and brake thermal efficiencies are obtained with the same mixture proportions and the determination of either as sufficient.

A consideration of the thermal efficiencies of Fig. 7 shows in nearly every instance an increase with one in the air-fuel ratio until the mixture becomes too lean for steady running of the engine. A value of 16 to 1 appears best for all loads except the two lowest and these would require richer mixtures for steady running. Such work as has been done on this subject at the Bureau of Standards has given similar results. The important thing to be noted is that the efficiency with any proportions with which the engine will operate is independent of the power developed. The same conclusion seems to have been reached by Mr. Ricardo, judging from the following statement:[45]

> I carried out a very large number of tests on about 40 different fuels to ascertain the relation between mixture strength, power and economy. Except for insignificant variations the characteristic efficiency and power obtained by gradually weakening the mixture is the same for all fuels and at all compressions excepting alcohol.

Failure of the engine to operate properly at very low loads with mixtures as lean as those giving maximum efficiency at greater loads seems to be due to dilution by the residual products of combustion. An analysis of this influence with experimental evidence to support this viewpoint has been given in the main portion of the paper and need not be repeated here.

It is concluded therefore that for present types of automobile engine the maximum power is obtained with air-fuel ratios of from 11 to 1 to 13 to 1 and the maximum efficiency at ratios in the neighborhood of 16 to 1, if the engine will operate regularly with such mixtures. Where dilution by the products of combustion necessitates richer mixtures the maximum efficiency is attained with the leanest mixture at which the engine will operate regularly.

[45] See *Automotive Industries*, Feb. 24, 1921, p. 460.

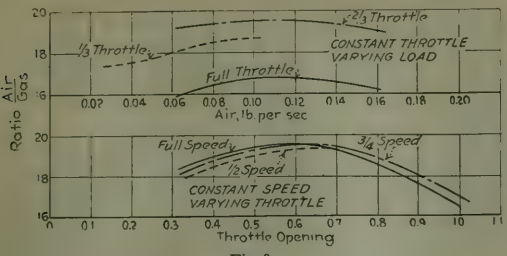

Fig. 8

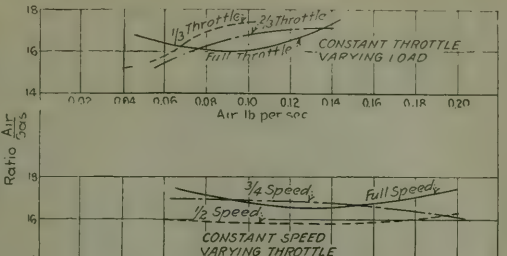

Fig. 9

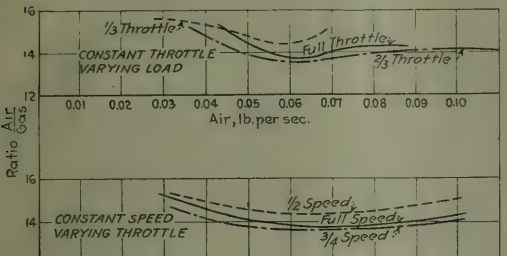

Fig. 10

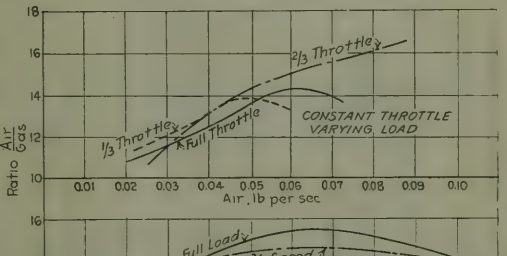

Fig. 11

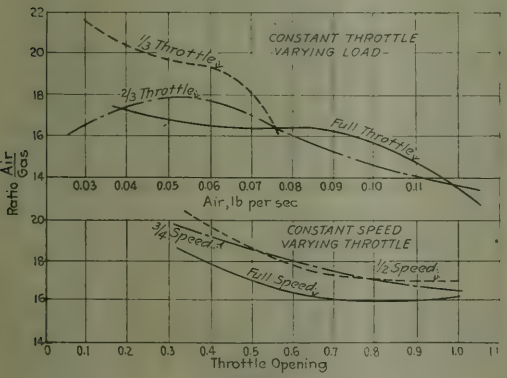

Fig. 12

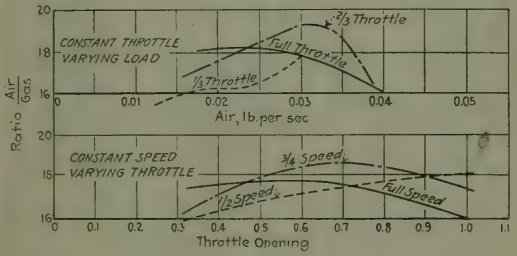

Fig. 13

FIGS. 8 TO 13—MIXTURE RATIOS WITH CHANGING LOAD FOR THREE CONSTANT-THROTTLE POSITIONS AND THE VARYING RATIOS OBTAINED AT A CONSTANT SPEED WITH VARYING-THROTTLE POSITIONS

APPENDIX 2

METERING CHARACTERISTICS OF SIX STOCK CARBURETERS[46]

As any wide departure of the mixture ratio from that corresponding to the maximum economy with a changing load on the engine may mean a serious waste of fuel, the load-mixture characteristics of several widely used carbureters are of interest. It might be assumed that since the pressure reduction causing fuel flow depends on the velocity, at a constant density, through the venturi in the normal type of carbureter, the gasoline discharge, and consequently the mixture ratio, would be determined solely by the weight of air used per second, or by the engine load. It is to be remembered, however, that a given weight of air may be used under very many different combinations of throttle position and manifold depression, corresponding with different relations of torque and speed of the engine. Now experiment shows that with the usual location of the throttle, throat suction and consequently mixture ratios are affected not only by quantity of air passing but by the degree of opening of the throttle itself.

With this effect in mind, mixture ratios were determined for six widely used carbureters for various rates of flow, each at several relations of throttle position and manifold depression. The resulting mixture ratios with changing load for three constant throttle-positions for these carbureters are shown in the upper portion of Figs. 8, 9, 10, 11, 12 and 13, respectively.

Since, in automobile operations, there seems to be a

[46] Contributed by R. L. Wales, Carbureter laboratory, Bureau of Standards, Washington.

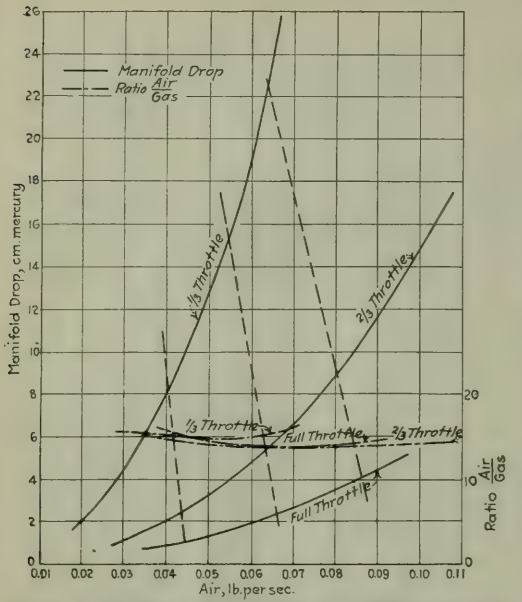

FIG. 14 — RELATION BETWEEN MANIFOLD DEPRESSIONS AND THE WEIGHT OF AIR PER SECOND FOR DIFFERENT THROTTLE POSITIONS AND ALSO BETWEEN THE AIR-FUEL RATIO AND THE WEIGHT OF AIR PER SECOND

tendency on the part of the driver to maintain a fairly uniform speed, opening the throttle on grades and on poor roads, and vice versa, it is apparently worth while to derive the relations of any variation in the quality of the mixture for different loads, or throttle positions, corresponding to different constant speeds. The method used in such determinations is given below. Fig. 14 is a typical curve, on which are plotted both manifold depressions and qualities against the weights of air per second for full open, two-thirds and one-third throttle.

[47] Contributed by S. W. Sparrow, M. S. A. E.—Mechanical engineer, Bureau of Standards, Washington.

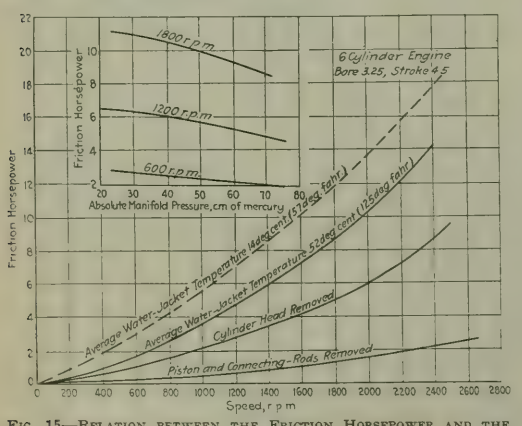
1800 r.p.m.
1200 r.p.m.
600 r.p.m.
6 Cylinder Engine
Bore 3.25, Stroke 4.5
Friction Horsepower
Absolute Manifold Pressure, cm of mercury
Average Water-Jacket Temperature 14 deg cent (57 deg fahr.)
Average Water-Jacket Temperature 52 deg cent (125 deg fahr.)
Cylinder Head Removed
Piston and Connecting-Rods Removed
Speed, r p m

FIG. 15—RELATION BETWEEN THE FRICTION HORSEPOWER AND THE SPEED

The air-flow for open throttle with a manifold depression of 4 cm. (0.1575 in.) of mercury is arbitrarily taken as that corresponding to full engine-speed with full throttle. The air-flow for three-fourths and one-half full-speed with full throttle, are taken as three-fourths and one-half the weight at full speed, corrected slightly for the difference in manifold depression.

The air-flow for other throttle positions than full, corresponding to each of these speeds, is determined thus: If the volumetric efficiency is assumed to be constant, the volume of air used, measured beyond the throttle, at manifold pressure, remains constant for constant speed. If volumes and temperatures are constant, weights vary directly as the absolute pressures. Hence the weights of air used at different throttle-positions for constant speeds will vary as the absolute manifold pressure.

On the above-mentioned plots lines have been drawn giving the variation of weight with absolute manifold-pressure, 76-cm. (3-in.) manifold depression. Any point on one of these lines corresponds to a constant volume of air per second, or to a constant piston speed. Intersections of these lines with the weight lines for different throttle-positions gives the weights used for the given speed and the throttle position. Referring to the corresponding quality curve determines the mixture ratio.

The lower portion of Figs. 8 to 13 inclusive show the varying mixtures obtained with different throttle-positions for the carbureters tested, at full speed as arbitrarily determined three-fourths and one-half speed. It may be mentioned that the volumetric efficiency is not exactly constant as assumed in the above work, but varies with both the manifold depression and the engine speed. Such errors as are introduced by this approximation, however, are not important. In studying these curves, attention should be focused, not on the actual mixture proportions which depend largely on the adjustment of the carbureter, but on the change in the mixture proportions that result from a change in the load. Any departure from the proportions that give the maximum efficiency at a given load, results in a waste of fuel.

APPENDIX 3

THE MECHANICAL EFFICIENCY OF ENGINES WITH PARTICULAR REFERENCE TO PART-LOAD CONDITIONS[47]

The mechanical efficiency of the engine is the ratio of the power delivered at the clutch to that developed in the cylinders. The difference between these two powers is used to overcome the internal friction of the engine, drive the auxiliaries and draw in and exhaust the charge. All of this power loss is included in the term "friction horsepower," although some of the elements are not due, strictly speaking, to friction. Thanks to the wide-spread use of the electric dynamometer, the determination of this friction horsepower is comparatively easy. It consists in measuring the power required to drive the engine without fuel or ignition, while keeping all conditions as nearly as possible the same as when the engine is operating under its own power.

Fig. 15 makes clear the need for maintaining the jacket-water temperature at its normal value during such determinations. At 1000 r.p.m. the friction with a jacket-water temperature of 14 deg. cent. (57 deg. fahr.) is more than 50 per cent greater than when the temperature is 52 deg. cent. (126 deg. fahr.). This difference is a consequence of the higher viscosity of the oil at the lower temperature. One should not infer from these curves that the proper viscosity for an oil is that which

gives the minimum friction. On the contrary, the viscosity must be high enough to prevent metal-to-metal contact, even when the oil is diluted with fuel. Nevertheless, the curves do illustrate the excessive friction-loss that will ensue from use of oil of a viscosity unnecessarily high.

A rough comparison of the magnitude of the several elements that comprise the friction loss is given by the lower three full-line curves. Similar comparisons have been made by Mr. Ricardo and by the engineering division of the Air Service at McCook Field.[48] All results show piston friction to be responsible for a large proportion of the total loss. At 2400 r.p.m., with the cylinder-head removed, the power required to drive the pistons and the connecting-rods is three times as great as that to operate all the rest of the engine.

It is frequently assumed that the difference between the friction horsepower measured under normal conditions and that obtained with the valves or cylinder-head removed represents the pumping loss. Values of the pumping loss obtained in this manner are considerably higher than those given by actual indicator-card measurements. It appears, therefore, that the removal of the cylinder-head not only eliminates the pumping loss but also reduces the piston friction through the change in pressures that results. This statement is made reluctantly because it has been found that the friction of the engine under power is not sensibly different from that when the engine is driven by the dynamometer, in spite of the lower pressures in the latter instance. At present the best that can be said is that measuring the pumping loss by this method of difference is open to question.

It is well known that the mechanical efficiency of the automobile engine decreases with a decrease in the load. One cause is the increase in the friction horsepower that results from closing the throttle. Fig. 15 shows this effect at three speeds, the absolute manifold pressures indicating the amount of throttle opening. That this is not the major cause of the low efficiency will be evident from Fig. 16. Here the mechanical efficiency and fuel consumption are plotted against the brake horsepower. The fuel-consumption calculations are based upon 0.55 lb. of fuel per i.hp-hr., a value that is assumed to be constant over this load range. The dash-line curves show results that might be obtained if the friction horsepower did not increase with the closing of the throttle. At 20-per cent load the upper curve shows a 20-per cent increase in the efficiency to be possible; that is to say, a car now going 15 miles on a gallon of fuel could then go 18. Even under these conditions, at 20-per cent load the specific fuel-consumption would be 40 per cent greater than at full load. The low efficiency of the automobile engine is thus seen to be due primarily to the fact that it normally operates at a small percentage of its maximum power. This reserve power, however, if not actually a necessity is at least a luxury that will not be willingly relinquished.

In conclusion, emphasis may well be placed on the importance of keeping the friction as low as possible because its influence is multiplied at reduced throttle. For example, under the conditions of Fig. 16, an increase of 1 friction hp. would increase the fuel-consumption at full load only 3 per cent but at 20-per cent load, 9 per cent. Small gains in mechanical efficiency thus justify the expenditure of considerable effort toward their attainment.

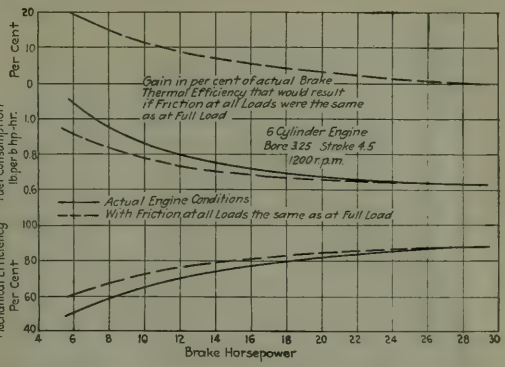
Per Cent
Gain in per cent of actual Brake Thermal Efficiency that would result if Friction at all Loads were the same as at Full Load
6 Cylinder Engine
Bore 3.25 Stroke 4.5
1200 r.p.m.
Fuel Consumption lb. per b hp-hr.
Actual Engine Conditions
With Friction at all Loads the same as at Full Load
Mechanical Efficiency Per Cent
Brake Horsepower

FIG. 16—RESULTS OF TESTS ON A SIX-CYLINDER ENGINE SHOWING THE RELATION BETWEEN THE MECHANICAL EFFICIENCY, THE FUEL CONSUMPTION AND THE BRAKE HORSEPOWER

APPENDIX 4

IGNITION TIMING[49]

The point in the cycle at which the ignition spark should occur in order that the engine efficiency may be a maximum is affected both by the speed of the engine and by its load. Many systems are constructed so that the timing of ignition changes with any change in the speed. There have been, in experimental use at least, devices which enabled the ignition timing to be controlled by the manifold pressure in an endeavor to meet the requirements of changing load. That the spark control-lever still appears on the steering-wheel of most cars, however, im-

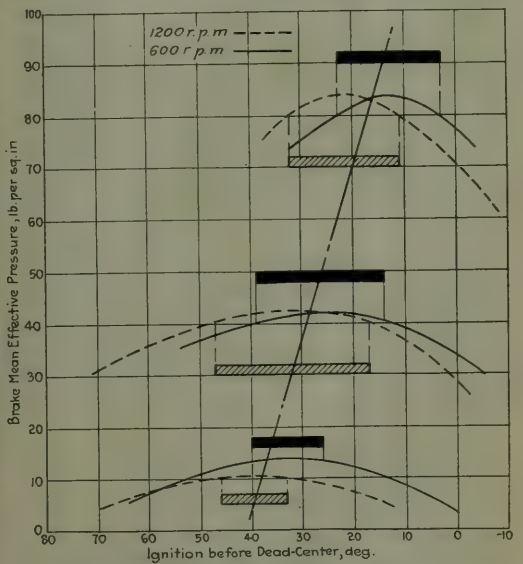

FIG. 17—INFLUENCE OF IGNITION TIMING UPON THE BRAKE MEAN EFFECTIVE PRESSURE

[48] See High-Speed Internal-Combustion Engines by H. R. Ricardo, published in THE JOURNAL, October, 1919, p. 317, and Experimental Separation of Engine Losses, published in *Automotive Industries*, June 10, 1920, p. 1338.

[49] Contributed by S. W. Sparrow, M. S. A. E.—Mechanical engineer, Bureau of Standards, Washington.

plies that most engineers consider the automatic devices unsatisfactory or too costly.

There seems to be a dearth of experimental data on the amount by which the timing should be changed with changes in speed and load. Fig. 17 is typical of the data that are required. It shows the brake mean effective pressure obtained with various degrees of spark-advance for two speeds and three loads. The length of the blocks adjacent to the curves indicates the range of spark-timing within which the brake mean effective pressure will not be more than 5 per cent less than its maximum value. Inasmuch as the fuel consumption does not change appreciably so long as the speed and the throttle opening are kept constant, a change in the brake mean effective pressure means a corresponding change in the thermal efficiency. A compensation for load changes that would give the spark-advance brake-mean-effective-pressure relation shown by the dash line would be fairly satisfactory for the two speeds tested. Data of this sort should be obtained over the range of speeds and loads at which the engine will operate in service.

It is a common belief among automobile drivers that the maximum efficiency is obtained with the maximum advance at which the engine will operate without knocking. Under the conditions shown by the lower curves no knock was obtained even with the maximum advance so that an adjustment in accord with the aforementioned belief would result in a *decrease* in efficiency of over 50 per cent. With manual control of spark-timing the possible advance should be limited to prevent this excessive loss of efficiency.

APPENDIX 5

Fuel Knock[50]

The phenomenon variously known as fuel knock, detonation and pinking has assumed so much importance because of the practical limitations it imposes on compression-ratio and consequently on fuel-economy that there has come to be much discussion and more speculation as to the exact nature of what takes place in an engine cylinder when this phenomenon occurs. However, neither the discussion nor the mass of information gained directly and indirectly from experiments has led to a definite understanding or even to a satisfactory theory of the nature of the phenomenon. The term detonation implies that something occurs in the cylinder which corresponds to the detonation of a high explosive. Such conditions are easily produced in explosive gas mixtures but there is scant proof that the same thing occurs in an engine cylinder. In fact, some of the experimenters most familiar with these phenomena doubt the possibility of such occurrence.

To clear up some of the indefiniteness, an attempt has been made to enumerate the various facts and observations concerning fuel knock and to discuss the bearing of these facts on the several theories that have been advanced to explain the nature of the phenomenon. Fuel knock as ordinarily understood is characterized by the following phenomena:

(1) A very sharp metallic noise
(2) Bright yellow flame within the cylinder
(3) Decrease in power
(4) Increase in heat rejected to the jacket-water
(5) High instantaneous cylinder pressure
(6) Destructive mechanical effects
(7) Occurrence of smoke in the exhaust
(8) Preignition, in most cases

Observations show that the occurrence and intensity of the knock are intimately related to the following factors:

(1) Chemical composition of the fuel
(2) Ignition timing
(3) Compression-pressures
(4) Mixture-ratio
(5) Position and number of spark-plugs
(6) Shape of cylinder and piston-head
(7) Temperature of the charge
(8) Cylinder temperatures

Aside from more or less random speculations, there are at least three rather definite theories or hypotheses presented as explanations of the character of this knock phenomenon. These are (*a*) what may be termed the mechanical-knock theory, which explains the sound by means of some mechanical knock or impact between parts of the engine mechanism, as for instance between cylinder wall and piston, or between shaft and bearings. This theory does not attempt to explain the cause of pressures which must exist to produce these mechanical impacts. On this theory it would be assumed that there is no necessary difference between the so-called fuel knock and any other purely mechanical knock, except that the former is primarily due to cylinder pressures, while the latter may be due to inertia effects, etc.

Another theory (*b*) is that proposed by Ricardo, which explains the sound and other phenomena as due to a sudden very rapid increase in cylinder pressures. It is assumed that a portion of the charge, compressed to the ignition point by the expansion of the portion first ignited, burns simultaneously, causing a very sudden rise in pressure. This theory does not contradict the former, but assumes that the sound may be produced either by the sudden distortion of the cylinder walls by gas pressure, or by mechanical impacts in the mechanism, due to the sudden pressure-increase. It seems to require the assumption that a fuel will show a tendency to knock somewhat proportional to its spontaneous-ignition temperature but it makes no attempt to explain the nature of the explosion or detonation which occurs in the compressed charge.

A third theory (*c*), which may not necessarily contradict either of the foregoing, is the so-called detonation-wave theory. According to this the process of explosion is explained somewhat as follows: When ignited the wave of combustion spreads out from the ignition point at a relatively slow but increasing rate. Under certain conditions before the flame has filled the combustion space, its rate of motion increases to what is known as *detonation* velocity, a velocity so high as to constitute practically the *simultaneous* burning assumed by Ricardo. An interesting theory regarding the nature of the chemical reactions which account for the increase in flame velocity has been proposed by Midgley.[51] Such detonation waves in gas mixtures were first discovered in 1881, independently by Berthelot and by Mallard and Le Chatelier. These velocities and characteristics are reasonably well understood. The velocities are from 1 to 2 miles per sec., sufficient to account for the sound and pressure effects which are observed in engine cylinders. But in direct experiments it seems never to have been possible to attain these velocities within the short space in an engine cylinder.

Of the three theories, the first does not attempt an

[50] Contributed by H. C. Dickinson, M. S. A. E.—Physicist in charge of power plants research, Bureau of Standards, Washington.

[51] See Combustion of Fuels in Internal-Combustion Engines by Thomas Midgley, published in The Journal, December, 1920, p. 489.

explanation of the phenomenon. Whatever causes the characteristic sound is certainly actuated by the sudden increases in cylinder pressure which have been measured repeatedly. The direct causes of these increases in pressure are of more interest than the source of sound and the only attempt at explanation of sudden pressure-increases is found in the theories (*b*) and (*c*); hence, these appear of greater interest. In considering the bearing of known and observed facts on these theories, it is important to note that the one important difference between the two theories is that (*b*) assumes that the cylinder pressures are true pressures produced by a sudden increase of pressure throughout the cylinder, while (*c*) includes the assumption that the high pressure may be localized impacts of the detonation wave. This means that the maximum pressure may not be by any means the same at different points within the combustion space.

The short metallic sound produced by fuel knock, particularly in light-weight cylinders, suggests the impact of a very light hammer on a heavy anvil. Observations of the velocities imparted to a light steel rod resting on the top of a Liberty engine cylinder during detonation show a number of interesting facts. For instance, it is found that under detonation conditions this cylinder-head is distorted with a velocity which might correspond to that of a tuning-fork, corresponding to that of a sound having a pitch above the range of the piano keyboard, or of the order of 4000 vibrations per sec. The action of the cylinder pressure is therefore entirely sufficient to account for the characteristic sound produced.

The characteristic bright yellow flame within the cylinder, which is observed to accompany the fuel knock, has been shown by stroboscopic observations to be of very short duration, occupying not over 10 deg. rotation of the crankshaft or about 0.001 of a sec. in time. Evidently the flame phenomenon is worthy of more careful study as to its exact time of occurrence, its duration and the characteristics of the intermediate products of combustion. Such information might go far to explain the knock phenomena.

A decrease in the power output accompanies knock but there seems to be no very close relationship between power and knock. For instance, the curves in Fig. 18 show the power output and maximum cylinder-pressure with reference to ignition timing. Throughout the range of peak pressures noted on the plot, fuel knock was present and at the highest pressures was violent; yet there is no marked irregularity in the horsepower curve. Apparently fuel knock of itself does not reduce the power but rather the conditions at which the knock occurs are not those for maximum power. Whether these conditions would produce the maximum power with a fuel that did not knock cannot be answered with certainty.

It has been observed that whenever fuel knock develops due to a change in the timing or pressure, or a change in the fuel, there is an abrupt increase in the heat rejected to the jacket-water. There are several possible explanations of this: (*a*) the increase in temperature and pressure may directly increase jacket losses by increasing radiation and connection to the cylinder walls; (*b*) the increase in pressure may increase leakage past the piston; (*c*) high-velocity detonation-waves, if they exist, may transmit energy to the walls by impact and (*d*) the burning of oil directly on the cylinder walls, due to high temperature of the charge, may add to the heat loss.

Whatever the immediate cause of this increase of heat loss, the fact is significant. According to either of the

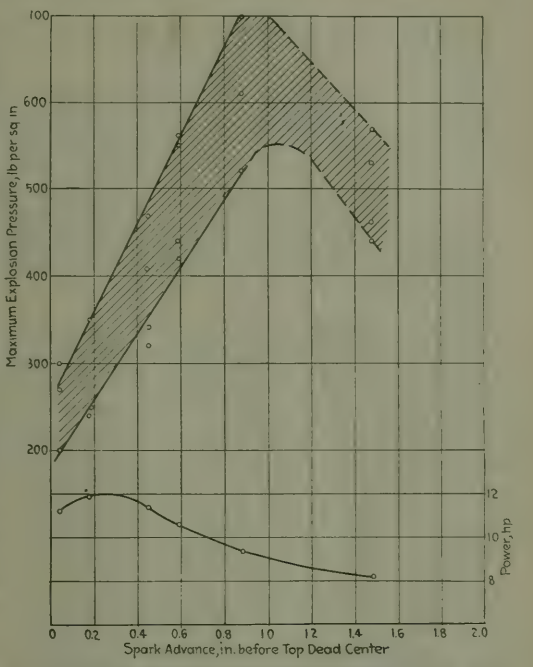

FIG. 18—CURVES SHOWING THE RELATION BETWEEN THE SPARK TIMING, THE MAXIMUM PRESSURES REACHED IN THE CYLINDER AND THE POWER DEVELOPED

two proposed theories, assuming localization and burning of a portion of the charge under increased pressure, it might be expected that the excess heating effect would be most pronounced at the particular location where this local combustion took place. Experiments to verify this by thermoelectric couples inserted in the cylinder in various positions with relation to the firing plug, show no significant difference in the temperature-rise for different locations. These observations seem to show that the excess heating effect during knock is *not* localized as might be expected. The effects of increased radiation and of combustion of oil would be in accord with these observations.

Extremely high cylinder-pressures have been found by different observers by various indicating devices. In one case with a compression-ratio of about 5 to 1 pressures of 1300 lb. per sq. in. were observed to occur consistently at each explosion; this pressure being the maximum measurable with the apparatus at hand. It is safe to assume that the maximum pressures were at least 1500 lb. and probably much higher. These pressures occurred with kerosene as fuel.

The amount and distribution of these pressures is of importance in relation to the two theories advanced. According to the Ricardo theory, the pressure may be uniformly distributed throughout the combustion-chamber, although this is not a necessary assumption. If uniformly distributed, the pressure must not exceed that which could be produced by burning all the fuel at constant volume at intake pressure and then compressing adiabatically to the final volume. In fact, due to the nature of the process, the pressure can hardly exceed

that which would be produced by compressing the charge adiabatically and burning it at constant volume under compression.

On the other hand, the detonation theory presupposes that the maximum pressures are localized and places no limit on their magnitude below the calculated impact-pressures of detonation-waves in the compressed charge. This limit would be between 5000 and 7000 lb. per sq. in., but it is important to remember that these are not true sustained pressures but resemble those produced by the blast from a high explosive, that is they would last only a few millionths of a second. It is very doubtful if any indicator in use is capable of responding to such instantaneous pressures, other than to register a kick, so to speak.

As for experimental results, some indicator observations seem to show differences in the maximum pressures for different locations of the firing plug; other results worthy of equal confidence fail to show any such differences whatever. At the Bureau of Standards the maximum indicator-pressure, the increase in combustion-chamber temperature and distortion of the cylinder-head have all been carefully analyzed for different locations of the firing plug to detect any localization of pressures and none has been found. This appears to constitute strong evidence that no marked localization of pressure occurs which depends directly on spark-plug location.

As noted above, the maximum pressures reached are occasionally as high as 1500 lb. per sq. in. at least. If they are normal uniform cylinder-pressures, they cannot exceed the pressures that would be produced by complete simultaneous combustion of the charge before compression, as stated. Moreover, from an examination of the pressure-change it is evident that comparatively little of the charge is burned much before dead-center; therefore, in practice, the knock pressures cannot exceed maximum computed pressures unless they are due to some effect other than normal combustion of the charge. Maximum pressure produced by the latter cause can be determined approximately. The maximum temperature reached on compression in the ratio 5 to 1 and combustion of a normal charge, taking account of dissociation, is given by Pye in *The Automobile Engineer*[12] as from 2500 to 2700 deg. cent. (4532 to 4862 deg. fahr.). If dissociation is neglected, the temperatures are computed as about 3000 deg. cent. (5432 deg. fahr.). As the effect of dissociation is to lower the temperature, with a slight increase in volume relative to temperature, take the higher figure. This temperature corresponds to, roughly, 3250 deg. cent. (5882 deg. fahr.) absolute. If, therefore, the pressure were 1 atmosphere before compression and 5 atmospheres after compression and the temperature 300 deg. cent. (572 deg. fahr.) absolute before compression, the pressure after compression and combustion has a maximum value of $5 \times 3250 \div 300$, or slightly over 50 atmospheres, which is about 750 or, say, 800 lb. According to Pye's results the temperature would be only about 500 deg. cent. (932 deg. fahr.) higher and the pressure only about 1000 lb. per sq. in., if the combustion took place before compression. Pye gives 700 lb. per sq. in. as the maximum attainable cylinder pressure. This neglects the volume of water vapor which would increase the pressures somewhat.

Remembering that these are absolute *maximum* pressures if Pye's results are to be accepted, pressures of over 1000 lb. per sq. in. must be due to some cause other than normal gas combustion. In other words, such pressures *cannot* occur *simultaneously* at all parts of the cylinder.

Destructive mechanical effects are somewhat difficult to interpret. Broken spark-plug porcelains, cracked piston-heads and burned-out bearings, as well as general evidence of excessive mechanical stresses, accompany continued detonation, particularly in aircraft engines. But none of these effects is subject to direct measurement. An index of the nature of the pressure-rises which accompany knock is had, as referred to above, by observing the height to which a light weight is projected from its seat on the cylinder-head. A measurement of this height and of the deflection of the cylinder-head per unit pressure-change leads to the following conclusions, which can be readily computed from the following data:

(1) The maximum height is 1½ in. The deflection of the cylinder head at this point is 0.0005 in. for each 100 lb. per sq. in. rise of pressure

(2) The rate of pressure-increase required to produce this effect is, roughly, 7,000,000 lb. per sq. in. per sec.

(3) The pressure was found to rise about 550 lb. per sq. in. above normal maximum when detonation took place, and to produce this rise at the above rate would require less than 0.0001 sec.

(4) For the Liberty engine cylinder, the combustion flame must traverse the explosive mixture at a rate of *at least* 4500 ft. per sec. to produce this observed rise of pressure. It is of interest to note that this figure is in fair agreement with the detonation velocities found by Dixon for explosions in tubes

The observed occurrence of black smoke in the exhaust may have many explanations. One of the most obvious, that it indicates incomplete combustion, is apparently contradicted by the observed fact that the *indicated power*, therefore the amount of energy liberated in combustion is at least as great with as without fuel knock. I know of no definite conclusions which can be drawn from this occurrence.

The frequent occurrence of preignition following violent fuel knock is a natural sequence of the increased amount of heat rejected to the jackets, spark-plugs, valves, etc. It hardly needs any other interpretation.

With reference to the several factors which affect fuel knock, the general consideration that the phenomenon is intimately connected with the process of combustion would indicate that any change in conditions would affect fuel knock.

The very marked effect of the chemical composition of the fuel and particularly of the addition of certain anti-knock compounds as demonstrated by Mr. Midgley and others shows the extreme sensitiveness of the phenomenon. In this connection, it should be noted that the comparison of different fuels by these observers has shown that some fuels which readily ignite spontaneously do not knock and vice versa. This seems to be strong evidence contrary to the spontaneous-ignition theory of Ricardo.

The effect of ignition timing has been shown by observations at the Bureau of Standards to be of very much more significance than previously supposed. For instance, it is proved that knock can be made to appear on cutting out one of two spark-plugs, or under other conditions to appear when the second plug is switched in; and these effects are apparently due solely to the changes in the effective timing of the combustion relative to piston po-

[12] See Character of Various Fuels for Internal-Combustion Engines by H. T. Tizard and D. R. Pye, published in *The Automobile Engineer*, February, 1921, p. 55.

sition. The use of two plugs in effect advances the timing. It is shown also that knock can be prevented much more readily and with less loss of power by careful regulation of ignition timing than had been supposed. However, it is difficult to draw any conclusions from these facts as to the nature of the fuel knock.

The other factors enumerated, such as the compression-pressure, mixture-ratio, temperature of the charge, and temperature of the cylinder, seem to offer no direct evidence as to the probable validity of the two theories under consideration. They might, however, afford valuable data if the nature of knock were better understood.

The number of ignition points and their relation to the shape of the combustion space seem to be of significance. It appears to be a fact that the larger the number of ignition points, and the nearer these are to all portions of the charge, the less is the tendency to fuel knock. The much discussed subject of turbulence appears to be probably of significance mainly as it affects the distribution of the burning mixture. Distribution of burning charge should be nearly equivalent to distribution of ignition points. Obviously the maximum rate of pressure-increase which can be produced by normal burning, occurs with the greatest amount of flame area, but the larger the number of spark-plugs the greater the total area of flame, at least at the beginning of the combustion; yet this maximum area never produces sudden pressure-rises of the order observed. Something beside normal rates of burning are, therefore, necessarily involved.

The conclusions to be drawn are as follows:

(1) The two theories of fuel knock, that of Ricardo and the detonation wave theory, do not appear to be essentially contradictory but make somewhat different assumptions as to the maximum pressure

(2) The sound produced by fuel knock can be adequately accounted for by the distortion of parts of the cylinder, without assuming any metallic impacts

(3) The excess heating-effect accompanying detonation does not appear to be localized in any particular portion of the cylinder, as might be expected from either theory

(4) No differences in maximum pressure when measured in different positions relative to the point of ignition have been definitely demonstrated, although some observations indicate them

(5) The maximum pressures measured seem to exceed those which could be produced by the normal explosion of the charge. This indicates that some phenomenon such as detonation must be assumed to account for the pressures observed

(6) The rates of increase of pressure which have been observed are such as to require the existence of some such disturbance as detonation, as an adequate explanation

(7) It has been shown that fuels which are particularly subject to auto-ignition by compression are not necessarily subject to fuel knock. This indicates that the spontaneous ignition theory of Ricardo, in its simplest form, is at least incomplete

From the foregoing, it may be concluded that whatever the phenomenon of fuel knock may involve, the observed facts are in reasonably close agreement with the theory that the high pressures and attendant phenomena are the result of an abnormal type of combustion which can be accounted for with a reasonable degree of completeness by the so-called detonation theory. The only serious discrepancy between this theory and the observed facts appears to be the failure to discover positions within the cylinder where maximum pressures and temperatures occur. If it can be assumed that the impact waves, which are taken as an explanation for the very high pressures, are capable of reflection within the combustion chamber, the hypothesis of localized maximum pressures is not essential to the theory.

[53] Contributed by S. W. Sparrow, M. S. A. E.—Mechanical engineer, Bureau of Standards, Washington.

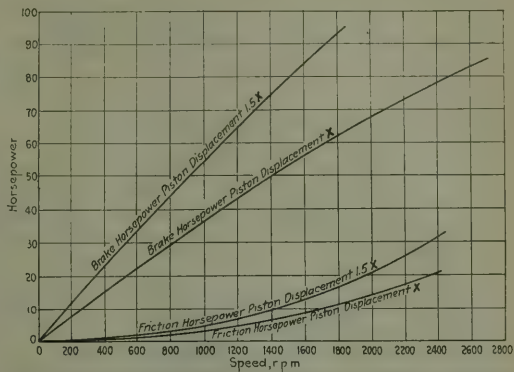
Horsepower
Speed, r p m
Brake Horsepower Piston Displacement 1.5 X
Brake Horsepower Piston Displacement X
Friction Horsepower Piston Displacement 1.5 X
Friction Horsepower Piston Displacement X

FIG. 19—COMPARISON BETWEEN THE BRAKE AND FRICTION HORSEPOWER OF A FOUR AND A SIX-CYLINDER ENGINE AT FULL THROTTLE

APPENDIX 6

RELATIVE MERITS OF LARGE SLOW-SPEED AND SMALL HIGH-SPEED ENGINES[53]

For comparison one engine is assumed to have a piston displacement 50 per cent greater than that of the other. Rear-axle ratios are taken as 3 and 4.5 for the large and the small engine, respectively, in order that substantially

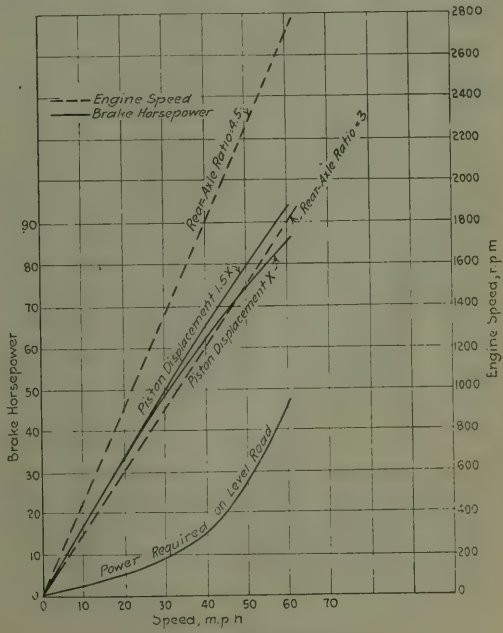

FIG. 20—BRAKE HORSEPOWER REQUIRED TO PROPEL A CAR AT VARIOUS SPEEDS ON A LEVEL ROAD

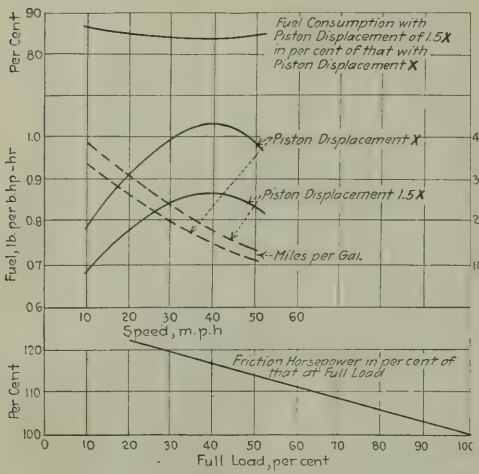

FIG. 21—THE RELATION BETWEEN FUEL CONSUMPTION AND THE FRICTION HORSEPOWER AT FULL AND PART LOADS

the same torque can be delivered to the rear wheels in each case. Fig. 19 shows brake and friction horsepowers for the two engines at full throttle. The data for the small engine were obtained from test and from these same figures the values for the large engine were predicted. Rather than inject a detailed analysis of the relation of friction losses to piston displacement, it is assumed that the increase in displacement is obtained by adding two cylinders to a four-cylinder engine and that the friction power is increased 50 per cent thereby.

Fig. 20 gives the brake horsepower required to propel the car at various speeds on a level road.[54]. The upper curves of brake horsepower give full-throttle results and thus show the power available at each car-speed. The grade that the car will negotiate and the car's ability to accelerate depend upon the amount by which the power given in the upper curves exceeds that given in the lower.

A fuel consumption of 0.55 lb. per i.hp-hr. has been used in the calculations for all conditions of engine speed and load. The possibility or desirability of obtaining a constant indicated thermal efficiency under all such conditions is discussed more properly elsewhere. If this efficiency remain constant for a given development of power, regardless of the speed at which that power is developed, the comparison will be essentially correct, even though the figure assumed for fuel-consumption be in error. Tests made thus far at the Bureau of Standards indicate that the efficiency for a given load is independent of the speed over the range of speeds covered in this discussion. One further assumption, the relation of friction horsepower at part load to that at full load, must precede the calculation of fuel-consumption per brake horsepower-hour. An approximate relation, derived from tests on an automobile engine and given in Fig. 21, has been used for this purpose.

In calculating the fuel-consumption in pounds per brake horsepower-hour, the first step is the determination from Fig. 20 of the brake horsepower developed at the speed selected. The same sheet gives the brake horsepower developed at full load at that speed and hence permits the percentage of full load at which the engine is operating to be deduced. Knowing this, the friction horsepower can be obtained by the relationship between the friction horsepower at full and part load, given in Fig. 21, the friction horsepower at full load being given in Fig. 19. Three steps remain: (*a*) the addition of the friction horsepower to the brake horsepower to obtain the indicated horsepower; (*b*) the division of the brake horsepower by the indicated horsepower to obtain the mechanical efficiency; (*c*) the multiplication of the fuel-consumption expressed in pounds per indicated horsepower hour (0.55) by the mechanical efficiency, to obtain values of fuel-consumption in pounds per brake horsepower-hour. Results calculated by this method are given in Fig. 21.

Percentage values, given in Fig. 21, show the larger engine to have a 15 per cent lower fuel-consumption than the smaller engine. This figure is unfair to the small engine, as the increased weight of the large engine means that the ability of the car is reduced. Published data show that usually in a series of engines built by any one company, the weight per brake horsepower is less the greater the horsepower. Let this effect be neglected to take care of any weight increase in the transmission and drive required by the larger engine and let the increase in the engine weight be 50 per cent. As the engine-weight is about 15 per cent of the car-weight, the weight of the latter will be increased 7.5 per cent. It is concluded, therefore, that the car has lost 7.5 per cent in ability and gained 15 per cent in economy. Furthermore, it is evident that increasing the large engine until its ability equals that of the small engine will still leave it somewhat superior from the standpoint of economy.

The foregoing analysis does not prove the superiority of either type of engine for every case. Engine cost, durability, relative ability for slow-speed operation, and many other factors must influence such a decision. There is a widespread belief that the small high-speed engine is vastly more efficient than the larger slow-speed type. The purpose of this discussion is to challenge that belief and to show the factors of major importance in the comparison of the two types.

[54] These data are taken from a paper entitled Fuel Problem in Relation to Engineering Viewpoint by A. L. Nelson which was published in THE JOURNAL, February, 1921, p. 101.

HIGHWAY TRANSPORT

HIGHWAY transport is not a single responsibility. Its efficiency depends not solely upon the highway engineer nor the automotive engineer but upon their hearty cooperation. It is just as harmful to limit the axle weight of trucks by laws based upon the present condition of roads, except of course as a temporary measure, as to expect that highway departments will respond to every caprice of automobile design. Highways must, however, be considered as only a means to an end and that end, national transport. It is just as necessary to pass regulations governing the nature and the strength of roads as to pass regulations controlling the weight and speed of the vehicles using them. The future highway must be constructed with regard to its use by self-propelled vehicles, and the automotive engineer, because of the heterogeneous types of road surfacing, must design and construct reasonably light vehicles capable of carrying its required load at minimum cost. Until that cooperation has produced the desired results a very rigid enforcement of the maximum-load regulation is an absolute necessity.—*Engineering News-Record.*

Air Transportation and the Business Man

By V. E. Clark[1]

Semi-Annual Meeting Paper

IT is more than 12 years since the first successful heavier-than-air craft flights were brought to the attention of the public. Generally speaking, we have not been immediately concerned in the business world with the advent of the new era in commercial progress ushered in by those first flights, and we believe we have gotten along well without the aid of aircraft, thus far. Yet, if a person wishes to travel or to send a letter from Chicago to San Francisco, he might use a prairie schooner or a Pony Express but he does not; if he wishes information from an office eight blocks distant he might walk there but he does not because it never occurs to that person to do a thing in any other than the quickest way. Probably they do not present the cheapest ways, directly, of transportation or communication, but the railroad, the telephone, the telegraph, the cable, the motor car and the motor truck, are necessities; progress, competition and habit have brought us to a stage such that we could not "live" without them because things would move too slowly.

As a fundamental fact, proved by history, can we not state that any vehicle or device that permits a material saving in time of transportation or communication between two points does in effect annihilate space and is therefore certain of becoming a necessity to the civilized world? Although the railroad and the motor car cannot be displaced, any thinking person knows that it will be impossible to prevent aircraft from taking a serious part in the activities of the commercial world; but it must be admitted that no air-transportation service has as yet been successful from the standpoint of returns on the investment. Many persons interested in aeronautics may wonder why and become discouraged, forgetting that the airplane is only 12 years old and that railroads and motor cars were, at the same stage of development, by no means valuable as money-makers.

I will attempt to answer the question as to what must be done before air transportation will become a serious factor in the transaction of business; endeavoring to give an honest exposition of the conditions which those interested in commercial aeronautics must meet. The thought is that most of the publicity given to civil aviation has been written by fanatics or by those who have had something to sell. Their published articles have, unfortunately, been so highly colored and often so impractical that the logical reaction on the conservative business man has been a deep-rooted suspicion of anything he sees in print on the subject. It is hoped that the treatment of the subject which follows may assist in balancing the scale of public opinion, and in clarifying and guiding the expectations and efforts of those who are associated in the development of the aircraft industry. It may in a measure serve to curb the unrestricted enthusiast, encourage the disheartened aviation devotee and arouse at least a tolerant interest among progressive business men. In the first part a few of the suggested uses of aircraft in the transaction of business are considered; the second part sets forth some of the present obstacles to the development of aircraft transportation and suggests means toward surmounting them. My hope is that discussion originated by those who may be interested will lead to constructive thought looking toward a solution of the problem.

Suggested Business Uses for Aircraft

Airships and airplanes are vehicles having such attributes as to place them in a unique class, as compared with other means of transportation. An airplane can carry a material thing from one point to another in a much shorter period of time than is required by any other known vehicle. It is inherently more speedy, and it can pursue a straight-line or a great-circle course which is the shortest distance between two points. Neither land nor water, nor mountain nor canyon, can interfere. Travel by motor car and truck is often impeded by bad roads. Aircraft do not require, for operation, the construction and maintenance of roads or railroads. In this respect, aircraft travel is comparable with travel by seacraft, except as to speed. Seacraft, however, cannot take the straight-line course between two points if land intervenes. All points cannot be connected by straight lines, and steam or electric trains must always lose time while dodging mountains and bodies of water. Delays at connecting points are unavoidable and schedules cannot be elastic because collisions would result; but the schedules for aircraft can be changed as exigency demands, without danger of collision. Sometimes the telegraph and the telephone expedite communication; but all of the world's business cannot be transacted in this way. If business did not require personal contact, we would not continue to crowd the passenger, the mail and the express trains. By using aircraft we can provide a platform, a "magic carpet," susceptible of being moved quickly to any point over the earth, and from which the country and the objects on the ground below can be seen, mapped or photographed, more completely and accurately than in any other way. Mindful, then, of these distinctive inherent attributes, let us recount some of the suggestions that have been made for using aircraft to aid and expedite the world's business, considering first the possibilities in the transportation of important confidential business or personal communications.

One can safely promise that before many years an airplane will fly from Chicago to New York in less than 3 hr. Even with mechanical development as it is today, this is possible.[2] We know that mail has been delivered in New York 33 hr. after it left San Francisco, constituting a saving of 3 days. To accomplish this, one pilot flew practically all night. It appears logical to assume

[1] M.S.A.E.—Chief engineer, Dayton-Wright Co., Dayton, Ohio.

[2] See Maintaining Airplane Engine Power at Great Altitudes, published in The Journal, April, 1920, p. 245.

that the real saving in time, to the business man, will be accomplished by night flights. Consider an hypothetical case of a business firm in Chicago which is suddenly confronted on Wednesday afternoon with a problem of vital importance, the solution of which depends upon information from a New York firm with which it has business connections. Perhaps the officials dare not use the telephone or telegraph, not only on account of the nature of the messages back and forth being too confidential but because complicated tables of data with accurate drawings must be transmitted both ways. Or, perhaps it becomes necessary to pass an important measure affecting the policy of the company and it is imperative that a trusted official go to New York for direct personal conference. To accomplish the desired result, which may involve millions of dollars or the defeat of a competing company, the answer must be returned from New York by Friday morning. Train mail would get the answer back possibly by Monday morning, or 3 days too late; but an airplane, navigating at night and operating on a regular schedule, could carry the complete query or the official, with data and drawings, to New York during Wednesday night, allow 16 hr. Thursday for the New York firm to work on the problem, and deliver the answer in Chicago early Friday morning. Another hypothetical case is that of a man drawing a $10,000 salary who is called upon to make a trip in the interest of his company to a point distant 200 miles in an air-line. The round trip by day train would require say 20 hr. and cost $25. The round-trip by five-passenger airplane today would require 4 hr. travel time and cost say $80. The man's time being worth $5 per hr. to his company, it is evident that airplane travel would be the cheaper.

If it seems that this is far-fetched and that such instances do not occur often enough to warrant an elaborate airplane service, let us remember that before the public became accustomed to the idea of the telephone or of the railroad it did not feel the need of them. Convenience and speed quickly cultivate habit. The banker and the broker are interested in knowing that one or two days' time can be saved each way every day between Chicago and New York, by night air-service, in the transporting and clearing checks, drafts, securities and certificates. Three days can be saved between the Atlantic and the Pacific coasts. Since so much time can be saved between points connected by train service as fast and as frequent as is humanly possible, consider what can be accomplished by aircraft in competition with boats or trains between points to which the route is circuitous or there are only one or two slow trains daily. Consider also the linking together of places which might otherwise be important except that they have no railroads. The man who is a director of corporations located in different cities and the man who has manufacturing interests in different towns will use the air as a medium for travel because they are eternally pressed for time. Such men can save say three-fourths of that part of their life previously spent in travel, or perhaps one-tenth of their whole life. Lord Cowdray has said, "The advent of the era of flight will lengthen our lives because it will enable us to do more in a given time than we have been able to do before." I quote also from Aerial Transport, by G. Holt Thomas:

> Regarding Commercial Transportation, the development of flying and of such an extraordinary power as that of the wireless telephone, may have influences which will be simply revolutionary, in the years to come, on the everyday life of the world. To be able to send the sound of our voices without the aid of wires over an increasingly wide radius of space; to travel through the air in all directions at a speed many times as great as that by land or sea; to rush at these great speeds with equal facility over land or water; and then to combine these two wondrous potentialities in a unified and perfect system that spreads its network over the whole of the globe, will give us powers which, when compared with our limitations today, will appear almost to render us superhuman. From the finite we shall seem to come almost to the infinite; time and distance, those limitations that are so irksome to the free flights of the human mind, will have lost very much of their hampering restriction. Men controlling vast industries, the captains who steer our great barks of commerce, will no longer feel that sense of irritation which comes from a constant struggle against imperfect communications. For we must remember that today, marvelous though the spread of science has become, we are still very much in the dark ages so far as international communication is concerned.
>
> Concerning the scope of the flying boat, the more one looks into this particular question the more impressed one is by its possibilities. Up some of the great rivers, for instance the Amazon, thousands of miles long, there is a teeming trade to be done, but it languishes simply owing to the slowness and difficulty of communication. Not only are there strong currents to be contended with, but the navigation of steamships often becomes a question of extreme caution owing to the presence of shifting shoals and other obstructions. Thus, stages of hundreds of miles must be traversed at a crawling pace; whereas, in a powerful flying-boat of modern type we have a craft capable of ascending into the air with an appreciable load and of following the course of these big rivers at an average touring speed of say 80 to 100 m.p.h., coming down to the surface of the water whenever a halt is deemed advisable and putting down or picking up passengers and goods just as is required. An organized flying-boat service operating on a regular time-table up these great rivers of the world would not only serve the existing trading communities on these rivers in a manner which is impossible at present but create and stimulate new trade in a way I think would be surprising, bringing indeed a new lease of life to these great water routes, and setting men to work along them with a new ambition and purpose.

The Dominion of Canada has more inland waterways than any country or province and it has very few railways. Water planes may be used not only for inspecting and surveying timber lands and making surveys for railroad construction, but for the transportation of mail, express, passengers, furs and supplies to places which are today inaccessible, but which may develop into large communities through airplane transportation. At present 12 patrols are operating daily in California and in Oregon to locate forest fires and reporting them by wireless telephone. The Department of the Interior states that this service is saving hundreds of millions of dollars yearly for the United States, and that plans are being laid for wide expansion.

One of the most valuable uses of the airplane will be for mapping. Photographic mosaics of parts of the country otherwise inaccessible have proved to be absolutely accurate and are in each case up-to-date. In projects for railroad construction airplanes will be employed for topographic work. Accurate topographic surveys can be made by airplane in a few hours, at a rate of, say, $15 per sq. mile, which it would take months and in some cases even years to make by ordinary surveying parties. In many cases these maps would be absolutely impossible

except for the airplane; certainly, their completeness of detail could not otherwise be approached. Daily aerial photographs of the freight yards in large railroad centers would give a much more accurate, complete and less expensive record of the location of freight cars. Officials, inspectors, supplies and mail can be transported through the air to inaccessible places where mining, timber or waterpower enterprises are under way. Even the transportation by air of valuable ore from some localities is being considered the quickest and least expensive method. An airplane can cross the Andes Mountains in South America at any point in 2 or 3 hr. Any other method of communication or transportation requires many days and sometimes several weeks. Deep-sea fishermen find that they can save time and money by locating schools of fish from seaplanes. Owners of large farms will make crop surveys at frequent intervals by airplane. In Texas airplanes are being used on large cattle ranches for locating breaks in fences and for finding and herding cattle.

Railroad companies may maintain airplane services to transport surgeons in case of wrecks and to convey injured persons to hospitals. Surgeons and specialists in the medical profession may often save lives when hurriedly called to another town, if they do not wait for slow trains. The relatives of those who are dangerously ill will use aircraft in a similar way. The delivery of city newspapers will be expedited and the aerial transportation of fresh meats, sea food and perishable fruits may prove to be profitable. Smuggling by airplane will be a menace to our borders, and the only means of prevention will be by airplane.

Although we are not going in for air transport seriously in America, as are England, France, Holland and Germany, we have in many ways more to gain than they have. Comparatively, we have tremendous distances to traverse, without complicated international agreements restricting the crossing of borders and landing on foreign territory. Again, our passengers need not be delayed and irritated by waiting for passports and customs inspections, which is really an important consideration.

Regarding the so-called sporting phase of aviation, there is fun in flying, a sense of power and thrills for the young man, but this phase does not help business unless we consider it as recreation or relaxation. The man off for a holiday can visit places which otherwise would require too much time. For instance, a business man might come from Detroit to West Baden often for the week-end if he could make the trip in several hours of exhilarating flying instead of taking a long, weary nerve-racking trip by dusty motor car or smelly train. A man in New York City might go deep into the woods for hunting or fishing if, instead of a week each way, only a few hours were required. He would see country he had never seen before, and from an entirely new point of view. The man whose office is in the heart of a city might consider the location of his home in an entirely different light if he could travel 50 miles into the country or along the shore in ½ hr.

The Impediments to Commercial Air Transport

In view of all these possibilities, why then has air transportation not been successful to date? What must we wait for before it can be a sound commercial proposition? A cautious business man may agree that these theories sound logical, but he will insist on knowing whether commercial aeronautics is a sound business proposition from the standpoint of returns on the investment. We are forced to admit that no air-transportation project within our knowledge has proved to be a paying proposition. To the question as to why a scheme that looks so promising cannot be made to pay, one man may answer that the general depression in business and financial circles makes people afraid to take hold of new things, especially if they are uncertain things and lacking in precedent. Another may say that with such a new and little understood device there is an inevitable period during which people must be educated up to it. People are instinctively afraid to get more than one foot off the ground, and this fear is fostered by the newspapers, which headline every airplane accident.

Let us not forget that the airplane is only 12 years old. The first steam locomotive ran on a track in Scotland in 1814. In 1829 there were 16 miles of track and one locomotive in America, and the first trans-continental track was completed in 1869. About 1860, when Pullman cars were proposed for comfortable night travel, an effort was made to pass a law prohibiting night trains as being too dangerous. In 1889 the telephone was 12 years old, and yet no one took it seriously. In 1897 the motor car was 12 years old and was looked upon with almost superstitious horror. Our forefathers were perfectly happy without these things but, today, we could not be. After the invention of the locomotive, it took 50 years for the railroad to start making money. The automobile, born 71 years later, began to pay in only 20 years. This is an era of industrial expansion, of progress in the scientific and commercial world, and the public is learning to take to new things more quickly. Nevertheless, to commercialize the airplane it is imperative to overcome the inertia of that inherent prejudice in the minds of the people against new things that they do not understand. There is a logical development period for this, as well as for any other sound business. Airplane companies have failed in trying to force airplanes on the public for commercial use before the people had any conception of the possibilities and the limitations of this new vehicle. The records prove that automobile companies had the same experience. The fear and inborn conservative prejudice against new "contraptions" cannot be discounted. Any enterprise whose leaders do not consider this phase is not sound. The vision of the directors is ahead of their business judgment. Those who risk capital in a high-sounding stock-jobbing enterprise starting on a large scale at this time, expecting immediate returns, are unfortunate.

Safe and Reliable Airplane Service

Before air transportation can be made to gain and maintain the confidence of possible users, it must be made safe and reliable. Here again one must admit that a regular scheduled service cannot be called safe and reliable until the engineer and the scientist have carried development further. For instance, any supposed expert who advises a prospective investor that safe and accurate airplane navigation and landing in thick weather and at night are assured today is doing the science infinitely more harm than good. It is only by telling the truth, even leaning toward the ultra-conservative, that we can consistently keep the confidence of the people. At a recent meeting in England the official announcement that from May 1919 to December 1920 inclusive 106,712 passengers were carried on 62,003 flights out of foggy London, covering a total distance of 1,556,000 miles and with only eight fatal accidents, in which one passenger was killed for every 10,000 carried and one was injured for

every 7000 carried, met with wild enthusiasm. This enthusiasm was sadly dampened when it was pointed out what a terrific loss would be recorded in railroad travel if the same percentage figures were to obtain.

The essential elements for a safe and reliable airplane service which is to operate either on regular schedule or under such provisions that a trip can be made at any time are included in a consideration of the airplane itself, its engine, its pilot, landing fields, the weather and navigation aids.

Considering first the airplane itself, a modern machine intelligently designed, well built of the proper materials and carefully inspected and maintained, can be made to fly safely over level open country. Under normal conditions there is almost no danger of structural failure of any part, of fire or any mysterious tendency to get beyond the control of a good pilot, either with the engine running or when it is shut off. One cannot say, of course, that the airplane of today is the perfected machine of the future, even as regards general outlines. In 10 years we may have a wholly different machine. Although we can now make airplanes that are comparatively fast and sufficiently strong, stable and controllable, we have seen nothing that looks like, or appears to the man who must take care of and repair it, or sells like a commercial article. The present airplane costs too much; requires too much time to build; has a construction not adapted to quantity production; is complicated to care for; is flimsy and goes to pieces rapidly; will not stand rough handling or weather; requires a large field from which to operate; uses too much gasoline and oil; is clumsy to transport when needing repairs; demands too long a time to remove or adjust the engine; and will not travel far enough or carry enough load.

As to the talk of giant airplanes capable of carrying a ship-load of passengers across the ocean within a few hours, one hesitates in this age to say that anything is impossible; but it is safe to say that, with such types of powerplant and methods of airplane construction as have been suggested and appear feasible, the airplane cannot handle more than say 6000 ton-miles of commercial cargo in competition with lighter-than-air craft. The increase, with size, of unit weight of sustaining surface alone appears to establish some such limit. Non-stop transoceanic flights by airplane would be extremely expensive, in view of the very small number of passengers possible. On the other hand, the airship appears, theoretically, to become more economical with increase in size, and will without doubt be used in transoceanic service. It cannot however, compete with the airplane in carrying comparatively small loads for short distances, either as regards cost or speed; for instance, 1 ton for 300 to 400 miles. In transcontinental service, with small loads, the airplane will beat the airship for cost and speed, even though the cargo must be relayed. The fields of utility of the airship and the airplane will not overlap.

First, let us try to build one of three types of airplane, each capable of safely getting into and out of comparatively small fields and having cruising speeds of 100 m.p.h. with cargo capacity and flight range such as (*a*) 600 lb. or three passengers, for 400 to 500 miles; (*b*) 1200 lb. or six passengers, for 300 to 400 miles; and (*c*) 2 tons, or 20 passengers, for 200 to 300 miles. Before we go further, let us learn to build such airplanes so that the cost of building, operating and maintaining them is not all out of proportion. When this is accomplished, a long step toward making a success of commercial aviation will have been made.

The advice has been given to sacrifice all else for speed, because speed is the raison d'être of the airplane. Speed is essential when bucking a head wind, but what good is speed if the cost prohibits its use? Consider a 200-mile trip. Our 100-m.p.h. machine makes it in 2 hr. A 150-m.p.h. machine does it in 1 hr. and 20 min. By train, over a curving route covering 250 miles, from 6 to 24 hr. is necessary. By automobile, from 9 to 12 hr. is required. The loss of 40 min. can be neglected, especially if the landing field at either end be a 1-hr. drive from the center of a city; it seems that other things are of more immediate importance.

There is much discussion as to whether commercial airplanes should be radically different from modified war machines. Regardless of the merits of the arguments, the fact is that almost all of our so-called commercial airplanes of today are modified war machines. One might venture the statement that a successful commercial machine must be wholly different from its military predecessor in that it must be cheaper and simpler. In war, the speed of an airplane, its ability to climb to great altitudes, its maneuverability and armament, must all be better than similar characteristics of the enemy's machines, regardless of cost or complications.

A phase worthy of thought is that during the war, when money was of small account and time was everything, immediate practical application at the sacrifice of research was the pressing need. It is perfectly natural that things seem to have gone slowly since the armistice. Our mental processes have not had time for readjustment. The result is that we have not got down to thorough research on the fundamentals. Problems upon which we had just begun research work before the war are not much further advanced today. Since the war, a great part of the energies of the members of the aircraft industry has been spent in endeavoring to realize financially on products constructed during the war, by trying to adapt them to civil uses. Such efforts are of course expedient, but the result has been that we still try to think of commercial aircraft in terms of war machines. Again, it is important to keep in mind the probability that air-transport companies have been forced to make the type of service, the routes and the points to be connected fit the machines available. The result may be that the logical routes for economy in business have been neglected. The present time should be considered the logical period for development. One might venture the suggestion that unless there be real danger of a national emergency in the near future, the Government should expend its funds during this period upon research, experimental construction and development, rather than upon a more than very limited production; but, in doing so, so far as may be in the interests of national economy, it should help to maintain facilities for future production by making such experimental work profitable to the industry. This appears to be purely a matter of national insurance.

Referring again to the cost of construction, the American manufacturer will say that quantity-production methods will accomplish the desired result. Here, then, is one problem which the engineer cannot solve without help and that help is not yet at hand. To illustrate, consider metal construction, which is undoubtedly better for rigidity and for endurance in varying climates; clever design for American production processes would certainly bring the cost of manufacture down considerably; but no manufacturer can afford to tool-up to build just a few machines and without such tooling wood is cheaper than metal. In this respect the engineer has arrived at an

impasse. Airplanes cannot be cheap until there is a demand, and there may be no demand until they are cheap. This is one answer to the query as to why we must wait for airplane development. However, let us remember that the automobile industry met and overcame this obstacle in time.

The airplane engine is probably much further developed than the airplane; aside from a radical change in principle. Consider some of the performances of airplane engines as indicative of their reliability, such as Alcock's flight across the Atlantic; the trips of the NC flying-boats; the flight of four machines from New York to Alaska and return; the flights from London to Australia and to Cape Town; our daily mail service from coast to coast and the crossing of the Rocky and Sierra mountains; the circling of the rim of the United States, and Coney's flight from coast to coast in two hops. Our best airplane engines can be said to be reliable from the standpoint of mechanical operation. Most of the forced landings are caused by stoppages in the fuel lines or in the carbureter jets, sometimes by leaks in the cooling or oiling systems, and by ignition troubles. However, lest engine designers wax complacent, let us reiterate, airplane engines cost far too much.

The development of pilots is the easiest problem of all. The war proved that among the young men of America there is no dearth of those of natural aptitude for flying, whose determined spirit, tempered by cool judgment and resourcefulness, make them ideally adapted to the work. To be sure, experience in navigating 'cross-country and in judging the approach to a bad field is essential.

Landing Fields

If the airplane designer keeps other things equal, such as engine power, empty weight and aerodynamic efficiency, the higher the flying speed is, the larger must be the field to land in safety; and the greater the load is, the larger must be the field to get out of safely. It has been maintained rightly that air transportation cannot become a fact until our cities and towns have landing fields. Here, again, we have arrived at what appears to be an impasse; temporarily at least. Before they vote for a municipal landing field, the men who are interested in the commerce of a given city must be convinced that the cost of purchase and maintenance will be more than balanced by the profit to the city's commerce. We may accuse them of lack of far-sightedness but, after all, is it not incumbent upon us to prove to them that air transportation will pay? The cost of landing fields at each of two cities, say 300 miles apart, is negligible as compared with the cost of a highway or a railroad connecting the two. The city gets all of the benefit of a landing field, whereas the benefit of a road is distributed along its entire length. From this is appears that the man in business in the city should be more interested in aircraft than the farmer.

Some of the requirements of a landing field are that

(1) It should be located so that the time required to travel to and from the business district of the city is as low as possible. Airplanes will not save nearly so much time when they connect two towns 100 miles apart if an hour is spent in getting to and from the airdromes. We can send mail to and from landing fields by pneumatic tubes, but it would be too expensive to send passengers in this way. It has been suggested that machines land on the flat roof of a large building. While this may eventually become safe and practical, it should not be permitted at this time

(2) The field should constitute an area of at least 50 acres of smooth level ground if there are no obstacles immediately adjacent. If there are surrounding obstacles, such as hills, buildings, trees and high-tension wiring, it should comprise at least 100 acres. These figures are minima; the larger the fields are, the safer they are

(3) The ground and subsoil should be of such nature and so drained that the field is never swampy or muddy

Regarding ways and means of financing a municipal landing field, it has been suggested that each municipal flying field be used as an Army reserve pilots' school, in addition to serving as a station for commercial transportation lines. Then that the Government pay a small percentage of the purchase price of approved fields; that the city pay the remainder; and that transportation companies be charged rental for land upon which they build hangars and shops and for the use of the field. Further, that Army reserve and student reserve pilots form a club and pay for building a clubhouse, except for a small percentage paid by the Government, and that the club be supported entirely by its members. In addition, that the Government furnish training airplanes, pay for the erection of hangars and shops for its own airplanes; and, for military training, pay for fuel and repairs. Some such scheme might prove most economical and effective in maintaining a large force of pilots in the event of a national emergency, at the same time lending Government aid to start aviation. France has gone further in her efforts to popularize aviation. On Sundays and holidays, according to reports, the Government airdromes are thrown open to the public and pilots, known to be qualified, are permitted to use the Government machines free of cost.

The Weather and Navigation Aids

We have seen that it is possible at present to control four of the elements essential to successful commercial flight, the airplane, the engine, the pilot and the landing field, in such a way that air transportation can be rendered at least sufficiently safe and reliable to warrant the confidence of the public, although it is not by any means perfect as yet; but it is not yet safe to fly 'cross-country in thick weather, in clouds, fogs, rain or snowstorms. We cannot control the weather and must learn to circumvent it. One might venture the statement that no form of transportation can become a really serious factor in the world's commerce unless trips can be made to any desired place in any sort of weather. A company cannot possibly afford to maintain expensive equipment unless it can guarantee service whenever required. The possible user must know that aircraft can transport him or his goods faster at any and all times than in any other way; he must be taught the habit of thinking of the matter in this way. A railroad cannot be successful if it has nothing but engines, cars and tracks; the telegraph, the telephone, block-signal systems, and automatic stops and switches are absolutely essential to its safe and reliable operation. Yet, just because the present airplane can cover the distance between two points many times as rapidly as any other vehicle, some people seem to feel that we are ready for commercial aerial transport.

There appear to be two big problems incident to all-weather flying; (*a*) we must fly when there are clouds or storms and because it is dangerous to fly in clouds, and often dangerous and fatiguing to fly below them, we must fly over them and develop means to navigate accurately; and (*b*) we must develop means to find a landing

station and to effect a safe landing on it, when fog extends down to the ground. These problems seem to offer tremendous difficulty but not until they are solved can we deserve the confidence of the public when talking of commercial aerial transport.

Gyroscopic compasses and turn indicators, if sufficiently accurate and reliable under various flight conditions, would assist greatly when flying above the clouds. A simple and practical bubble sextant for the observation of heavenly bodies might be useful on long flights. But these, even though they be made to function with perfect precision, will not suffice. Before air transportation can be a big thing, we must dot the country with radio "lighthouses," unless some better scheme be developed. In addition, airplanes should be equipped with wireless telephones and the ground stations with directional wireless sets. Simultaneous readings of direction of the aircraft would then be taken by two or more ground stations, the latitude and longitude would be determined by plotting to get the section of azimuth lines, and the airplane pilot would be kept informed continuously of his location. The most economical distance between ground stations must be determined through actual service. There must be no danger of interference between these and other radio sets; this should be regulated by Federal law. The cost of installation and operation of such ground stations will be negligible as compared with that of railroad telegraph and block-signal stations. Some such system, or a better one to accomplish the purpose, is just as necessary to successful navigation of the air as the airplanes themselves, not only for flying in thick weather but also at night.

Landing in Thick Weather

This promises to be a much more difficult problem, but it is just as important of solution.. There are two phases to be considered (*a*) finding accurately the regular airdrome, gliding into it so as to cross its border at the correct altitude and in the right direction and landing safely without striking an obstruction; (*b*) landing safely and avoiding dangerous obstacles, when a landing while lost in the fog is unavoidable through failure of the powerplant.

It appears easily possible to develop means to indicate to the pilot, while he is flying in a thick fog, when he has arrived in his glide at the proper height above the ground. This is all very well, provided one is landing on a perfectly smooth unobstructed surface; but what appears at present to be almost impossible is to insure against collision with some dangerous obstacle when landing in a dense fog in strange country. We may eliminate all of the other dangers of commercial 'cross-country flying in the near future, but this one may remain. But let us remember and take heart, for if we have a reasonably reliable powerplant, reserve fuel and means for accurate navigation, we can discount the possibility of forced landings in strange country. Nothing is 100 per cent safe. We do not worry about travel by train or motor car, although statistics have shown and continue to show many serious accidents. Records show that 11,000 deaths resulted from automobile accidents in the United States in 1919.

The first phase of this problem is a difficult one, that of landing at a regular station in a fog. It may be possible to dispel or precipitate a fog for a few minutes over a small area and to a height of say 200 ft. However, methods so far suggested for accomplishing this are prohibitive because of their excessive cost. Special radio "localizers" and sound signals, such as the rapid firing of a gun, supplemented by the radio telephone and by powerful searchlights throwing beams of peculiarly penetrative qualities, have been suggested; but we know of no really satisfactory development. Continuous meteorological reports, transmitted from Weather-Bureau observation-stations to the airdromes, the ground radio stations and thence to the airplanes in flight, will be necessary. Rules must be developed that are more dependable than at present for determining the direction and velocity of wind currents at various altitudes, and for predicting storm paths. The Weather Bureau might use self-recording meteorological apparatus elevated by kite balloons at their observation stations. A real aid in 'cross-country flying would be to have the names of the towns and villages painted in large type on the roofs of the railroad depots or the largest buildings. Illustrating the apathetic attitude of the public toward aviation, possibly an excusable one, it has been found impossible to persuade the towns to do even this much. Some conception is thus afforded of the complexities and expenses incident to an air-transport service, but the problems are by no means solved as yet. The scientist and the engineer can go far toward solving them, in the laboratory and at the experimental flying station, but, after all, will not the final solution come only after continued tests in actual service? This has been proved in the development of the motor-car and of all such mechanical systems. As a matter of fact, the engineer cannot get a real conception of the problem before the particular device has been tried out and its weaknesses developed under hard practical service conditions.

The first route used to develop means for navigation and landing should be of such nature as to typify the hoped-for eventual lines; that is, it should be at least as difficult as the average. The equipment for flying and the apparatus and facilities on the ground should be complete and, because most of them are experimental, subject to constant change. Such a project, if it is to give the real solution, will require not only time, experience and the efforts of capable scientists and engineers, but a large amount of money expended by wise business administrators.

The Financial Aspects of Aviation

As to whether present conditions in this country are such that a cautious business man, a possible investor, will go in for such an enterprise, once more we seem to be at the end of a blind alley. We have tried to show that an air-transport service projected now must operate at a loss for a year or two at the best, because it would not have nor deserve the confidence of possible users until further developments have been perfected; and yet, before aviation can get on its feet, there must be at least one line operating continuously for a long period. This is necessary not only to develop apparatus but, equally as important, to instill into people the habit of taking air transport seriously, gaining their confidence.

Let us analyze the reasons back of the refusal of conservative business men to go in for aviation. Assuming that there are in this country many men of means who believe in the future of aeronautics and have sufficient vision and far-sightedness to be enthusiastic over it, we will confine our analysis to this class. First, many of these men feel that they have not the time and others have their capital tied up in some enterprise which promises quicker and more certain returns. But supposing there are men in this country who are willing to lose

money on such a project until the time when the education of the public meets mechanical development, the odds are against their going in for it. The absolute lack of Federal legislation controlling or regulating civil aeronautics is an unsurmountable obstacle. The administrators of any enterprise could have no confidence in their position before this condition was remedied.

As an illustration of the dangers incident to the lack of Federal control, no measures exist to prevent any person who represents himself to be a pilot and an engineer from buying or even building any sort of airplane, setting it up in a vacant lot and starting to carry passengers wholesale. The airplane may be dangerous for one or more of many reasons; the original design may be bad from either aerodynamic or structural considerations; the workmanship may be amateurish or the material weak. Our so-called flyer may leave his machine exposed to the weather and to the tampering of the townsmen and, either through ignorance or carelessness, the inspection and maintenance may be ineffective. The field may be small or surrounded by dangerous obstacles. The flyer himself may be reckless, or lacking in skill, or both. Could one acquainted with aviation do otherwise than wax vehement in protestations against his friends taking airplane rides under such conditions? It is marvelous that the number of accidents, not only to passengers and to people swarming over the field, but to those on the streets, are not more numerous than they are. There is no law to prevent the unscrupulous promoter from exploiting the amateur designer or the inventor, and soliciting stock subscriptions for a visionary enterprise which can have no hope of success and does well if no innocent passengers are killed during trial flights. How can a serious enterprise be promoted when such conditions exist? Insurance rates must remain prohibitive and even though a legitimate air-line might operate for several years with 100 per cent of safety and reliability, it cannot hope to maintain the confidence of the public if accidents continue because of the operations of irresponsible and uncontrolled amateurs.

Sensible and comprehensive laws are of immediate importance; laws enforced by capable inspectors controlling the original construction, the maintenance of the equipment, the personnel, including the pilots and mechanical forces and the scope and methods of operation of all aeronautic enterprises.

At present the Army, Navy, Marine Corps, Post Office, Geological Survey, Coast and Geodetic Survey, Forest Patrol, Customs and Coast Guard are more or less interested in aeronautics. It appears that there is little co-ordination of their aeronautical activities. As a result there must be duplication of effort and loss of money.

Government Aid

We have seen that any group of men undertaking an air-transport enterprise at this time must be prepared for heavy financial losses, for a time. Perhaps there is no group of men in this country that is willing to undertake such a project and capable of carrying it to success. In this connection, the unfailing optimism and generosity of men like Mr. Uppercu, of the Aeromarine Co., are doing much to pioneer civil aviation in this country. The consensus of opinion among the more progressive military experts appears to be that the next war will be won in the air. If the United States is to be prepared, we must not lag in aeronautic development. We must also be ready with plant facilities and trained organizations for building up-to-date aircraft. It is a duty to carry insurance for our Nation in this way; perhaps our taxpayers cannot afford to maintain huge military air fleets in peacetime because they represent an investment for which there is no possible return until war occurs. A less expensive way of pushing development and of maintaining facilities against an emergency might be for the Government to help legitimate commercial enterprises until they can stand on their own feet.

France, evidently appreciating the national value of aviation, has gone in for governmental subsidy, even in her present state. For the fiscal year 1921-1922 the French Parliament voted $6,500,000 to be used entirely for helping commercial aviation. The subsidies to be granted are a subsidy for purchase and a subsidy for public transport. Subsidies will be granted only to French subjects and companies employing French material and French pilots and personnel. The subsidy for purchase consists of a grant by the State of half the value of machines employed for transport. No subsidy will be given for aircraft built before July 1, 1920. The purchaser receiving the subsidy must undertake to keep the machine in good condition and guarantee that he will not sell the machine or allow it to leave France without special consent. The company must own such a number of airplanes that there will be one machine for every 100 flying-hr. expected. It must employ at least one pilot for every three machines and one mechanic for every 300 hp. utilized. In addition to certain grants for purchase and for depreciation, for the pay of the crew, the cost of fuel and the like, the Government pays 9 cents at the present rate of exchange for every passenger-mile. and the passenger pays 9.5 cents per mile. For goods carried, the Government pays 0.00275 cents per lb.-mile, and the shipper pays 0.0825 cents per lb.-mile. But, although our Government helped the railways to start, by condemning and granting them great stretches of land, and helps merchant vessels by maintaining lighthouses and lightships, the direct subsidy of aircraft is not countenanced. A subsidy has many disadvantages, not only to the Government but to the corporation, and a subsidized enterprise is not a healthy one. This form of aid may, then, be eliminated.

The Air Mail

The most logical form which Government aid can take appears to be the letting of definite contracts to responsible corporations for the delivery of mail. Let this be done on a really big scale by forming a network of air-mail routes covering the entire country. Bring places now inaccessible into touch with the world and do not confine aerial-mail routes to cities which already have fast and frequent train service. Reach the places, rather, which have very slow mail service at present. Let the contracting companies be paid at a sufficient rate to insure them against loss, with additional bonuses for exceptionally good records for regularity and consistent speed.

Suppose we grant that the Government will, for a few years perhaps, lose money in endeavoring to carry mail in this way. The delivery of mail will be expedited at least, if capable people handle the service. The important point is that our Government would be fostering development, and maintaining facilities for the production of aircraft in the event of an emergency, at comparatively small cost. In a short time, the companies operating the various lines will have developed means for flying regularly and economically with a high degree of safety and reliability.

Underlying Principles of Electrical Ignition

By Benjamin F. Bailey[1]

Detroit Section Paper *Illustrated with* Diagrams

MY purpose is to point out some of the underlying facts that we must consider in connection with electrical ignition. I shall try to make them plain by the use of some analogies with mechanical things. Let me speak first about the simplest form of electric ignition, one that is now practically obsolete but formerly was very common. Fig. 1, at the left, shows the circuit of the old touch-spark or wipe-spark ignition. A battery is shown at *a*, a coil of wire wound around an iron core at *b*, and at *c* a contact-breaker which opens and closes. The iron core consists preferably of a bundle of iron wire. In this type of ignition that contact breaker is located inside of the cylinder and is opened and closed by the motion of the engine. There is also a switch *s* on the outside to turn the ignition off and on. There is a very close mechanical analogy between this circuit and an automobile starting under the influence of a constant force. At the right in Fig. 1 the car is being accelerated from rest by a force applied in the direction *a b*. This corresponds with the electromotive force applied by the battery to the coil.

In the electrical device we have current; in the automobile we have velocity. The velocity of the automobile corresponds with the velocity or speed at which the electricity is moving through the circuit. The mass of the car corresponds with what we call the inductance of the coil; and, lastly, the friction of the car corresponds with the resistance of the electric circuit. The car resists being moved on account of friction. Electricity resists being moved due to resistance. We have what we call inductance in the electric circuit. If an attempt is made to change the velocity of the car, the change is resisted by the inertia of the car. Similarly, any change in the current through a coil is resisted by the inductance of the coil. If the circuit be closed, a current

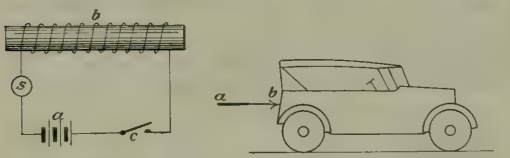

Fig. 1—Diagram of the Old Touch-Spark Ignition Circuit Which Is Analogous Mechanically to an Automobile Starting under the Influence of a Constant Force

passes through the coil and sets up a magnetic field. As the current grows it sets up lines of magnetism through the iron core. As these lines grow they induce in the wire an electromotive force which resists the rise of the current. The system is conservative and always resists any change. If the current is flowing it dislikes to stop and if it is not flowing it dislikes to start. In that respect it is exactly analogous to the automobile, which resists being started and requires brakes to stop it. This growth of the magnetic lines explains why we have an inertia effect in electric circuits. Applying a constant force to the car at the right in Fig. 1 would be analogous to applying a constant electromotive force to the coil at the left in Fig. 1. In the case of a car it will start, accelerate gradually and finally reach a certain definite limiting speed when the frictional resistance is just enough to balance the force. If we plot the curve of velocity and time, as in Fig. 2, it will rise and finally become horizontal. The final value will depend upon the frictional resistance and the force applied. In the case of the electric circuit precisely the same thing happens. The current starts, rises and gradually attains its final value, which is determined by the resistance and the electromotive force of the circuit. In the mechanical case we have the velocity finally equal to the force divided by the friction. In the electrical circuit we have the current, represented by I, equal to E/R. In neither case is the velocity or the current attained instantly. It takes time to do it. The exact expression for this curve is as follows:

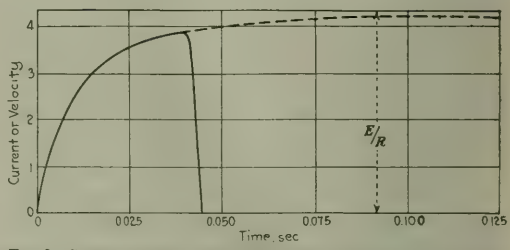

Fig. 2—Curve Showing the Time Rate of Growth of an Electric Current or the Velocity of a Car Accelerating Gradually

$$I = E/R\ (1 - \epsilon^{-Rt/L})$$

in which

I = the current at any instant
E = the electromotive force of the battery
R = the resistance of the entire circuit
L = the inductance
t = the elapsed time following the closing of the circuit
ϵ = the base of the Naperian system of logarithms

The instantaneous value of the current at any time is equal to the electromotive force divided by the resistance, multiplied by a reducing factor. As time increases the reducing factor increases, the value finally reaching unity. The current then equals the electromotive force divided by the resistance.

The analogy can be carried further. As we accelerate the car, we expend energy and the car acquires a certain store of energy. As we increase the current through the

[1] Professor of electrical engineering, University of Michigan, Ann Arbor, Mich.

induction-coil we are similarly storing energy. The expressions in the two instances are again analogous. In the case of the car we know that the energy stored is equal to one-half of the mass of the car times the square of the velocity. In the electric circuit it is one-half of the inductance times the square of the current. The corresponding mathematical expressions for the stored energy are $\frac{1}{2} Mv^2$ and $\frac{1}{2} LI^2$. If we stop the car suddenly with the brakes, what happens? We increase the friction by putting on the brakes. In the case of the electric circuit, we have a similar thing. When we open the circuit that does not mean that we stop the current instantly, but we introduce the resistance of the air-gap which, comparatively speaking, gradually stops the current. The current in stopping follows a curve similar to that which the car follows while it is stopping. In either case the energy must be expended somehow. With the car the brakes get hot. In the case of the electric circuit the energy is expended in the gap and the gap gets hot; in other words we have a spark there which is capable of igniting a mixture of air and gasoline.

We also can extend the analogy to the force that is developed by the stopping. In the case of the car, if we try to stop it suddenly the force required is very great. If we stop it gradually, a much smaller force will suffice. In the case of the electric circuit, if we open up the gap rapidly there is a large induced electromotive force, just as though we had stopped the car suddenly, for instance, by a collision. The more sudden the stopping is, the greater the force will be. So, the more quickly the gap opens the higher is the electromotive force that will be developed. This system has become more or less obsolete, although it has great advantages

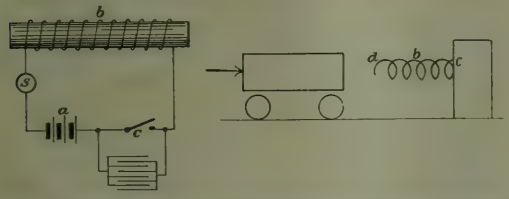

FIG. 3—DIAGRAM OF AN ELECTRICAL CIRCUIT IN WHICH A CONDENSER IS INTRODUCED AND THE CAR IS CONSIDERED TO STOP BY STRIKING A SPRING RATHER THAN BY APPLYING THE BRAKES

in its favor. It is unquestionably the simplest device from the electrical standpoint, but the mechanical complications, such as the difficulty of keeping the points in order, have caused its disuse, except perhaps for large stationary engines.

A slight modification brings us near to what we have in the secondary coil, or the regular induction-coil. If we shunt a condenser across c in Fig. 1 we have the arrangement shown at the left in Fig. 3. A condenser is built up of a series of sheets of tinfoil or similar material, separated by an insulating medium. The current cannot pass through the condenser because of the insulating material between the plates. A certain amount of electricity can, however, be stored in a condenser. The amount is proportional to the force applied to push it in; in other words to the electromotive force.

We can represent an analogous set-up in the case of our car. Instead of putting on the brakes, we will allow the car to hit the spring shown at b in the right portion of Fig. 3 which is fastened at the point c and loose at the point d. Closing the contact c at the left in Fig. 3

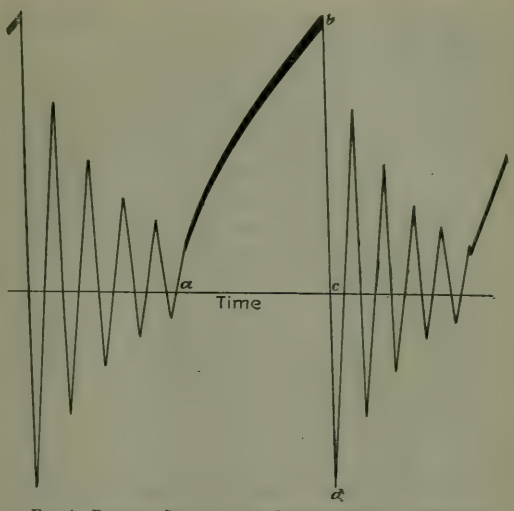

FIG. 4—DIAGRAM SHOWING THE OSCILLATION OF AN ELECTRIC CURRENT WHEN THE CIRCUIT IS OPENED

is analogous to giving the car at the right a push. Opening the contact c is equivalent to allowing the car to hit the spring in Fig. 3 and become attached to it. The analogy between the spring and the condenser is perfect. The distortion of the spring is proportional to the force applied to it and so is the distortion in the electric condenser; that is, the quantity of electricity that is stored in the condenser is proportional to the force applied to accomplish this result, just as the distortion in the spring is proportional to the force applied to it.

Suppose the car goes up against the spring at b and is coupled to it in some way so that it cannot get away. It will compress the spring, shoot back, go forward and keep oscillating until the friction finally brings it to rest as shown in Fig. 4. Exactly the same thing happens in the case of the electric current. We close the circuit, which corresponds to starting to push the car. The velocity increases as shown by the line $a\ b$ in Fig. 4. At b we open the circuit, which is analogous to having the car hit the spring. The current is brought to zero rather quickly, but it swings past the zero value, increases to a negative value of $c\ d$, again decreases, reverses and so on, oscillating in this way for some time. We can control the frequency of electric oscillation in the same way that we can control the frequency of oscillation of the car, or just exactly as we can control the period at which a car bounces on the springs when it hits a bump. There is absolutely no difference between the two phenomena.

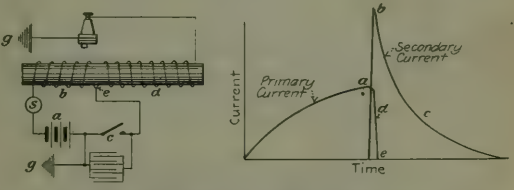

FIG. 5—DIAGRAMMATIC VIEW OF A TYPICAL IGNITION CIRCUIT IN USE AT THE PRESENT TIME AT THE LEFT AND AT THE RIGHT THE CURVES OF PRIMARY AND SECONDARY CURRENT

If we want the oscillations of the car to be slow, we make it very heavy, or use very flexible springs, or do both. If we want them to be quick and sharp, we make the car lighter, or the springs stiffer. We do exactly the same thing in the case of the electric circuit. If we want the oscillation to be quick, we stiffen the condenser; that is, we use a condenser that will not store so much electricity for a given force, just as we stiffen a spring so that it will not deflect so much for a given force; in other words, we use a smaller condenser. Another way to quicken the oscillations would be to reduce the inductance of the coil *b;* that is, to reduce the property which corresponds to mass by putting fewer turns on it. We can go further and calculate the frequency of the oscillations, if we know the constants involved in the problem, just as we can calculate the frequency with which a car will oscillate when it hits a bump, if we know the weight of the body and other constants. As a matter of fact, these electrical oscillations generally require in the neighborhood of 1/3000 sec.; that is, there will be about 3000 complete oscillations in each second.

To modify the simple diagram shown at the left in Fig. 3 and make it correspond with the coils that we actually use today, we put a secondary on the coil as shown at the left in Fig. 5. The secondary winding is usually wound over the primary winding, but is drawn separately to simplify the diagram. If we close the circuit at the left in Fig. 5, the current will rise in the primary of the coil. This means that the magnetic lines will increase in number in the coil, starting from zero. This will induce electromotive force in the secondary of the coil, at the "make." However, the rise is fairly slow. The electromotive force induced is dependent on the rate at which the magnetic lines are cut. If we cut the lines slowly, the electromotive force is small; if we cut them fast, it is high. Hence, the electromotive force that we get in the secondary of the coil is comparatively small. It is small enough that the spark cannot jump the gap on the spark-plug. If we had no spark-plug, we would have the current flowing in the secondary at the make but with the spark-plug there we get no current if everything is all right. When we reach the point *b* in Fig. 4 and open the circuit, if the condenser is properly adjusted, the rate of cutting of the magnetism will be exceedingly rapid, and consequently a very high electromotive force be induced. If no current flows through the circuit, for example, if the wire is detached from the spark-plug, the primary current will continue to oscillate, just as it did without any secondary winding on the coil, and we shall have an oscillating secondary electromotive force. But ordinarily that is not what we get or what we want. As a rule, we have enough electromotive force in the secondary so that the current jumps across at the spark-plug gap at the left in Fig. 5. In this case we have little or no oscillation. It is perhaps difficult to understand why this is so but, as soon as the spark jumps, it begins to absorb the energy that was stored in the electric circuit. The action is the same as that which takes place in a car equipped with shock-absorbers. The friction resists the motion, absorbs the energy and therefore kills out the oscillation that we would otherwise get. So, in the electric circuit, if we put in a resistance and allow the current to do work, if the resistance is low enough it will kill the oscillation entirely; the current then comes down to zero and stops there. Practically, we never succeed in transferring all the energy from the primary to the secondary of the coil. We always have some oscillation left. The curves of primary and secondary current are shown at the right in Fig. 5. The secondary current is much smaller than the primary, but is here plotted to a larger scale to make the diagram clearer.

What happens in the secondary is exactly what will happen if we have our car in motion, shut off the driving force and allow the car to coast. It will slow down gradually until it comes to a stop, and follow a curve very much like the curve of the secondary current, shown at the right in Fig. 5. The primary current is large; in an average coil it would amount to from 2 to 5 amp. at the point *a*. In the secondary the current at *b* would be perhaps 0.1 amp.

Curves like those of Figs. 2, 4 and the one shown at the right in Fig. 5, are obtained by an oscillograph. The oscillograph is an ammeter with the parts made so light that they can keep up with the very rapid fluctuations of the current. When the current fluctuates very rapidly through an ordinary ammeter, the needle does not have time to follow and it will simply stand still and indicate an average value. In the oscillograph the moving parts are exceedingly light and have so high a natural period of oscillation that they can keep up with any ordinary variation. A very small mirror reflects a beam of light against a moving film and traces out its path along the film.

In the actual ignition system some other points must be taken into account. Fig. 6 shows the curve of rise of current in an induction-coil. We do not always get the same distance along that curve. If the car is standing still and the breaker-points on the ignition switch are closed, the current reaches the highest possible value which is E/R. But when the engine is functioning and the breaker-points are opening and closing rapidly, there will not be time enough to get full current value. If the engine is running slowly, we get say the value shown at *a;* if it is running twice as fast, we get the value shown at *b*, and if four times as fast, we get the value shown at *c*. The energy we have stored in the coil is equal to $\frac{1}{2} Li^2$, or one-half the product of the inductance and the square of the current, just as the energy stored in a moving car is $\frac{1}{2} Mv^2$. This means that we will not get anywhere near so much out of the coil at high as at low speed, because the contact is not closed nearly so long. Thus it will be seen that the faster the engine is running the less will be the energy stored in the coil each time the contact is closed. The energy delivered is less than the energy stored, but can be taken as roughly proportional to it. In Curve *I* of Fig. 7, the values of the energy per spark with the revolutions per minute of the engine are plotted. This curve is of course derived from Fig. 6. Its exact shape depends upon the characteristics of the coil, the number of sparks per revolution and the percentage of time that the breaker-points are open. The design must be such that the ignition is satisfactory at the highest possible speed of the engine. At the lower speeds the spark will then be somewhat stronger than is absolutely necessary.

Battery and Magneto-Ignition Similarities

The modern high-tension magneto has an induction coil with primary and secondary windings. The primary is short-circuited most of the time by contact points which open when the spark is to be produced. These points are shunted by a condenser. So far we have everything that we have in the battery system, except the battery. I said an induction-coil; it is actually called an armature, but it is the same thing, practically. It consists of some laminated iron around which two coils of wire are wound; one coil is

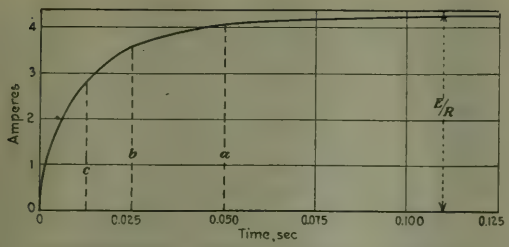

FIG. 6—CURVE SHOWING THE RISE OF CURRENT IN AN INDUCTION COIL

of comparatively coarse iron wire, and the other is of very fine wire. In that sense it is an induction-coil. Including the breaker, we have all the elements of the battery system, except the battery itself. We substitute for the electromotive force of the battery the electromotive force which is generated directly in the primary coil by the rotation of the magneto armature. The electromotive force generated by the armature of the magneto is an alternating one and not the steady, direct, electromotive force furnished to the induction-coil, because the magnetic flux is cut first in one direction, and then in the opposite direction, generating a to-and-fro electromotive force instead of an electromotive force in one direction. The fact that the current is alternating does not bother us particularly, provided we break it at or near the time it has its maximum value. If we should break it when it is down near zero, we would not get much of a spark, but if we break the current when it is near the top of its wave, the conditions are very much the same as in the case of the induction-coil system.

One point of difference which is rather insisted upon by the makers of magnetos is the fact that in the secondary we have not only the electromotive force which has been induced by the very rapid dying down of the primary current, but we have the electromotive force which is due to the cutting which continues after the points are open. The curve at the right in Fig. 5 shows how the primary current rises and then drops very suddenly, and how the secondary current rises very quickly and then tapers off. After the circuit has been broken, the secondary current is left entirely to itself. It is like a car that has been given an impulse, left to coast and finally comes to rest. That is not true with the magneto. We keep on applying a push to the electric circuits, just as though we had the clutch partially in on the automobile and applied a slight push instead of allowing it to coast freely. This is because we keep on generating electromotive force. The result is that the secondary magneto-current does not die down so rapidly as that from a coil. This effect is the so-called follow-over. It is the current which the magneto men say produces the "whiskers" on the spark.

We can now compare the current we get from the magneto with that we get from a battery-ignition system. The electromotive force in the magneto is supplied by its rotation. Obviously, if the magneto is standing still, there will be no electromotive force. Obviously also, as it speeds up, the electromotive force increases in proportion; so we have very much the same condition as if we had a battery-ignition system in which we started with very low electromotive force at slow speed and gradually increased it in proportion as the engine ran faster. Hence, instead of giving a constant push we give it a much harder push at the higher speed. The current in the magneto rises along very much the same curve as is shown in Fig. 6, but the steepness of the curve depends upon the speed of rotation of the magneto. The higher the speed is, the more rapid is the rise of current but, on the other hand, the shorter is the time during which the current is allowed to run. The result is that the energy per spark increases with the speed, but not so fast as we might expect. In fact, there may be an actual drop in energy per spark at very high speeds. Curve *M* of Fig. 7 shows approximately what happens. Obviously, neither of the curves of Fig. 7 represents ideal conditions. If the battery spark is strong enough at high speeds, it is too strong at low speeds. This is however highly desirable when trying to start a cold engine with a low battery. On the other hand, it is difficult to make the magneto spark strong enough at low engine speeds.

There are various things that can be done to improve either one of these conditions, perhaps especially the coil system. It is claimed by those who favor the coil that a very hot spark at very low speed is advantageous. I think every one will admit that this is true. The magneto men say they get plenty anyway, because magneto-equipped cars run successfully; but, under the very lowest speeds, certainly we would get more from the coil than we would from the magneto. On the other hand, the spark grows weaker as we reach the high speeds when using the coil. The coil-makers claim that they get all that is needed and that at high speed not so much energy is required to ignite the mixture successfully as at low speed. The mixture itself is likely to be much better and the compression is perhaps slightly better. This is certainly borne out to the extent that we do get successful ignition with the battery system at high speed, just as we get successful ignition at low speed with the magneto. The magneto manufacturers, on the other hand, claim that they have the hotter spark at high speed, which they argue is advantageous in that the mixture burns more rapidly and develops more engine-power. The battery-ignition man says that the spark-plug points burn away with the strong current. I shall not attempt to decide between the two. I have used both and have had trouble with both.

The much-debated question of whether a hotter spark gives more power in an engine has interested me and I

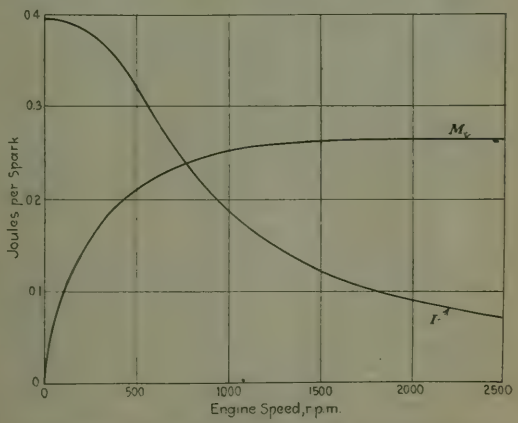

FIG. 7—CURVES SHOWING HOW THE ENERGY PER SPARK FROM AN INDUCTION COIL DECREASES WITH AN INCREASE IN THE ENGINE SPEED AND THE ENERGY IN A SPARK SUPPLIED BY A MAGNETO INCREASES

have experimented to a certain extent in regard to it. Suppose I have a sheet of paper that I want to burn. If I apply a small match to the corner of that paper it will burn. The question is, will it burn any faster if I use one of the old-fashioned big matches? I think it makes no particular difference, provided it burns at all. I admit that it is more likely to ignite from a big match if conditions are bad but, provided it does ignite and does burn, I cannot see that the size of the match is going to influence the speed with which the entire sheet of paper will be consumed, and that is what we are concerned with. I contend that the analogy is a good one. In a cylinder the flame travels with considerable velocity but it is a finite velocity just as there is a finite velocity of flame-travel for the sheet of paper. Provided the mixture burns at all, I cannot see that it makes much difference whether we have a large or a small spark. If we have the hot magneto-spark it might ignite the mixture when the coil spark would not ignite it at all; but, provided we do get an explosion, I believe that the speed of propagation will be about the same whether the spark is weak or strong.

I have been talking about the energy per spark; joules per spark means just the same thing. The joules per spark has been used by the Bureau of Standards in the comparison of coils, but I think it is not the best basis of comparison. The important thing is not the joules per spark, but the power. Work is, of course, power multiplied by time. I think it does not make much difference what happens at *c*, shown at the right in Fig. 5, but that it makes very much difference what happens at *b* when the spark first passes. The power is surprisingly great for a very short time. It is in the neighborhood of 50 watts, or about as much as a good-sized incandescent lamp takes; but it remains at this value only for an infinitesimal time such as perhaps 0.000001 sec. It raises the temperature of a small portion of the space to a high value for an exceedingly short interval of time. The power that is applied there is the thing that matters primarily. It is not power entirely either; it is power per cubic inch.

Of course it cannot be denied that, in the case of ordinary bodies, the temperature attained is a function of both the power expended and the time. In the case of a spark, however, the conditions are such that the heated matter can and doubtless does get away quickly from the place where the heat is being developed. In other words, I believe that the spark at the instant of formation is very thin and grows rapidly as the spark continues. A small volume of air between the points quickly becomes very hot and the volume then increases, the temperature remaining nearly constant. As I said before, I have no direct proof of this, except some visual inspection of sparks and the above considerations. If a direct proof could be obtained it would greatly clarify our ideas.

Short and Long Sparks

As a further illustration, let us compare two sparks, one short and the other long. Roughly, the gaps are in the ratio of 2 to 1. All dimensions of the sparks are also in the ratio of 2 to 1. I think that is practically what takes place with a longer spark. I am very sure it spreads out more and occupies more space. If we compare the volume of those two sparks, it will be as 1 to 8. If we make a thing twice as great in every dimension, it has eight times the volume. Let us assume that the power is in the ratio of 1 to 8, twice the voltage, four times the current. The power per cubic inch however is 1 to 1. The two sparks will therefore be approximately equally hot and the igniting power will be the same. It is true that the larger spark has a greater surface, but that would not make much difference in the rate of flame propagation, as I see it. It would help a little to spread it and the flame would not have to travel so far, but that is a very small matter which I think we can safely neglect. If this analysis is correct it indicates that the power per cubic inch is the proper criterion to use in determining the igniting power of a spark.

To illustrate further by referring again to the sheet of paper, I light it with a match. It does not matter how long the match is, provided the paper lights; the length of the match has absolutely no effect on the rate at which the flame will travel across the sheet of paper. Just so in the case of electric ignition. The follow-over part would have almost no effect because the mixture is already burning. Certainly, as soon as the mixture begins to burn, the heat liberated is much more than the spark could possibly give. It is conceivable that we might not get ignition at the very beginning, and that the follow-over part might possibly ignite it toward the end of the stroke. In that event the explosion would not be worth very much, because it would occur so late in the cycle of the engine.

I have performed one very simple experiment which indicated that, provided we get ignition at all, the power developed by the engine is independent of the strength of the spark. There are many variables in the usual engine-test. For example, we may make a test during a certain hour, and another test several hours later. Perhaps the barometric pressure is not then the same, or the mixture, or the spark pressure, or the degree of advance. A number of things may affect it. I think I left no chance for argument. I did not test as between magnetos and battery systems, but I tested as between hot sparks and weak sparks.

The test was made upon an engine equipped with battery ignition. The power output was measured by an electric dynamometer. A throw-over switch was arranged so that the number of cells used to furnish current to the coil could be changed instantly by throwing a switch. As first tried, the ignition voltage could be changed from 6 to 12, *thus increasing the energy per spark four times.* I got the engine running smoothly so that the balance-arm of the dynamometer did not move. I could throw the switch over one way and then the other; there was no difference; nothing happened. The dynamometer-beam never moved and the speed remained absolutely constant. I tried this with all sorts of combinations of cells. I did find that when the voltage became too low the engine began to miss, and of course I obtained more power on high voltage but, so long as the engine did not miss, I could not detect any difference. I tried making the mixture poorer and found that the engine would sometimes miss with the lower voltage whereas it would not miss with the higher voltage. But if everything was all right, there was absolutely no difference in power. I tried it at several speeds; running light and running loaded. The results were the same. I submit that this is a far better test than making a run with a battery and then making a run with a magneto at different times. There was absolutely no chance for change. The spark-advance was exactly the same and the conditions were absolutely identical. The above-mentioned test may be taken as an argument either for or against the magneto. It is wholly understandable that a magneto might be better than a coil system under certain circumstances. I can under-

stand that if the mixture were very poor and the engine running at high speed, the magneto might fire the charge when the coil would not, admitting that there is more energy in the spark. On the other hand, I can understand that at very low speed the coil might fire the charge when the magneto would not.

The amount of variation in the energy per spark that has been used in practice is rather astonishing. I have made a number of tests, and some results are shown in Fig. 8. Some years ago I had a car equipped with a well known magneto, the curve of which is shown at *a*. The curve of a typical battery system is reproduced at *b*. The output of the magneto seems absurdly low, yet I found no fault with the magneto. It ran all right. The engine could not be started on the magneto and a battery was necessary but, aside from that, the engine ran and operated all right with that exceedingly weak spark. The curve *d* shows typical results from a modern high-tension magneto. The spark has sufficient energy to ignite the mixture readily at cranking speeds. The curve *c* is that of a battery-ignition system giving more energy per spark than the coil of curve *b*. All these ignition systems worked fairly well, and there seemed to be enough energy with any of them. This is stated to point out that we can get fairly good ignition through a very wide range of energy per spark. Roughly, measured in thousandths of a joule, these ran from 25 as a minimum to about 325 as a maximum, a range of about 13 to 1, throughout which the operation was fairly satisfactory.

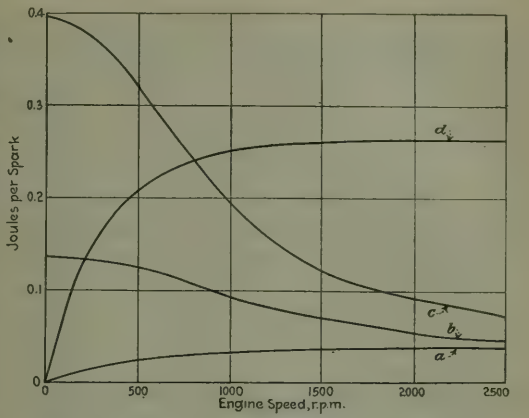

FIG. 8—CURVES SHOWING HOW CHANGES IN THE ENGINE SPEED PRODUCE VARIATIONS IN THE ENERGY PER SPARK SUPPLIED BY MAGNETO AND BATTERY IGNITION SYSTEMS

SPARK LAG

Another point worth noting is the lag in an ignition system. There was a large lag in the old-fashioned battery ignition in which a vibrator coil was used because, after the circuit was closed by the primary contact-maker, the current had to grow until enough current was obtained to magnetize the coil and pull the vibrator open. There was a definite time-interval before the vibrator would open and produce a spark, but there was not a definite angle. The angle was very small at low speed, and very large at high speed. Also, in the case of the so-called open-circuit system wherein a trigger is tripped and a contact piece is allowed to fly over, make contact and then spring back, we get the same sort of lag because there is a definite time-interval between the tripping of the trigger and the time when the spark is made. The lag is fairly large. It has to be taken care of by automatic advance or by allowing plenty of manual advance. With the ordinary coil of the so-called closed-circuit type the lag is very slight indeed. When the breaker-points start to open the current starts to decrease very fast. It does not come down in a straight line; the decrease is comparatively slow at first and then more rapid. At a certain point the rate of change becomes great enough to give sufficient voltage to make a spark jump across the gap of the spark-plug. The true time of lag is the time from *a* to *d*, at the right, in Fig. 5. The time-interval from *a* to *e* is ordinarily not over 0.0002 sec., so that the time from *a* to *d* would be in the neighborhood of 0.0001 sec. This gives a lag of 1 deg. with an engine operating at 3000 r.p.m. In the case of the magneto we have almost the same thing. The breaker opens in the same way and the current has to decrease in the primary of the armature before the spark passes in the secondary. However, there is this difference. In the magneto at high speed, due to the higher electromotive force, we do not have to drop so far on the curve before we get a sufficient rate of change to make the spark jump. The amount of advance required with the magneto is, therefore, slightly less than that with the battery system. The difference is very small. It amounts only to a fraction of a degree, assuming well designed apparatus.

THE DISCUSSION

FRED WEINBERG:—What is Professor Bailey's opinion of the type of magneto in which the magnetic flux is broken instead of the circuit in the primary? This type of magneto came out some 10 years ago and was made by a company in Massachusetts.

PROF. B. F. BAILEY:—I have heard of that, but I do not know enough about it to have formed an opinion.

MR. WEINBERG:—When you speak about magneto ignition, do you have primarily in mind the type ordinarily known today as the Bosch magneto?

PROFESSOR BAILEY:—Yes, the ordinary Bosch type.

MR. WEINBERG:—You did not include the so-called Witherbee type of magneto, which in my opinion forms a very strong bridge between magneto and battery ignition. It possesses the strength of battery ignition, together with the strength of magneto ignition, and eliminates the weakness of both.

T. J. LITLE, JR.:—Is it not a fact that as long as the temperature of the spark is well above the kindling point of the mixture to be fired, the ignition will be satisfactory, irrespective of whether the spark is produced from the magneto or the battery system?

PROFESSOR BAILEY:—I think that is true.

MR. LITLE:—That is the real situation. I thought possibly an analogy might exist in kindling a piece of paper, either with a match or an oxy-acetylene flame. The paper does not ignite better in the one case than in the other.

PROFESSOR BAILEY:—That is a very good illustration.

MR. WEINBERG:—There is no doubt that an oxy-acetylene flame would start the paper burning more quickly than a match would. It will take the oxy-acetylene flame considerably less time than the match to start the first part of the paper burning.

PROFESSOR BAILEY:—If my analysis of the two sparks is correct, one is not any hotter than another. It is simply bigger. Perhaps the analogy that I used between a small match and a large one more nearly fits the case.

MR. WEINBERG:—The length of the match seems to me to be of no consequence, so far as the length of time for burning the paper is concerned. I submit for consideration that the heat of the flame is of consequence as to bringing the fiber of the paper to the temperature at which it will start burning. If it takes some length of time for the fiber to come to the temperature of the flame of the match, then a time-element is involved and the hotter the flame is, the more quickly it will start the paper burning. An analogy is to take that same piece of paper and put it in sodium silicate, commonly known as water glass. I did this and could not light it with a match, but I could light that same piece of paper with an oxy-acetylene flame and it would burn.

PROFESSOR BAILEY:—I think that is a perfectly proper comparison. In other words, I think a hotter magneto spark might ignite a mixture that a weaker spark would not.

MR. WEINBERG:—Ten years ago I owned a runabout that had the old-time spark which was generated by a dry battery. Sometimes, when I had difficulty in starting, all that was actually necessary was to take my old battery cells out and put new ones in. When I took the spark-plug out and tried the spark, the spark was all right with the old cells. I never could make out why it was that it would not start with the old cells and would start with the new battery.

PROFESSOR BAILEY:—There is no question about that. When I first got a car with a magneto on it, I did not know what to do in case of such trouble. When the battery ignition stopped, after strengthening the battery it would be all right.

MR. LITLE:—A keg of gunpowder as compared to a cylinder in a gas engine would be the better analogy, rather than a piece of paper. The keg of gunpowder can be set off with a match as quickly as with the oxy-acetylene flame.

MR. WEINBERG:—I cannot agree, because gunpowder and dynamite are very unstable compounds and gas mixtures are rather stable. I prefer to take an intermediate step such as in the case of Thermit, which is a compound of aluminum powder and iron oxide. A quantity of Thermit cannot be started burning with a match. That is known. If a strip of magnesium is used as an intermediate agent, and ignited, the Thermit will start to burn from that. This is a point that is well worth investigation. Why does not the Thermit start burning with the match, when it will start with the piece of magnesium which has previously been ignited by that match? In other words, some intermediate agent is used for the purpose of bringing the ignition temperature up to that of the Thermit; the match is not hot enough to set the Thermit aglow. After the Thermit is once started burning it continues very rapidly; but that is after the magnesium has been used. That is in favor of my contention that the original ignition temperature is the prime factor of importance; that is, to bring the gas mixture to the temperature of the igniting medium. This Thermit analogy is submitted to illuminate that particular point.

PROFESSOR BAILEY:—We all recognize that it requires a certain amount of heat to start combustion, and the weak spark will not ignite a certain mixture when a hot spark will. I had one car which frequently would not start in the winter because the spark was too weak; when the engine was cranked by hand, thus relieving the battery of the starting current, it would start at once.

A MEMBER:—Suppose a spark in a cylinder 4 in. square and that the spark was 3 in. in diameter. That would ignite the mixture much more rapidly, no doubt. The final burning of the mixture would be much quicker than with a very small spark, but it would not be a desirable thing in ignition because it would approach detonation; in fact, it would be detonation. In other words, the spark would blast its way through the mixture that filled the entire cylinder. It would undoubtedly burn more rapidly, but it would not produce a gas; it would produce an explosion.

PROFESSOR BAILEY:—There is no doubt about that. If I light the sheet of paper on two corners, it will burn faster than if I light it on one corner only. Every one admits that more power is obtained from two sparks than from one. With four sparks I suppose it would be better.

C. F. JEFFRIES:—I think it will be found that the matter of gas turbulence is of more importance than the location of the spark-plug and the number of sparks per cylinder.

PROFESSOR BAILEY:—There is no doubt that is a big factor.

O. E. BARTHEL:—What is your opinion as to the desirability of having more sparks than one in igniting gas in a cylinder? I tried at one time to explain to a court the operation of a vibrating spark-plug, in relation to synchronism and the lag of the spark. We tried to use oscillograph photographs, but found them practically useless as we could not depend upon the operation. It was practically impossible to reproduce a photograph with the same coil and under the same conditions. We gave it up. Finally, we constructed an apparatus by mounting a paper disc and arranging it so that the spark would perforate very fine holes in the disc. This gave a correct curve of the lag of the spark at each setting. By taking the disc off the machine and holding it to the light, an exact view of every perforation was obtained. That was the way we explained to the court the operation of the spark coil, the lag of the spark and the synchronism.

PROFESSOR BAILEY:—There is no doubt either in theory or practice that more power is obtained with two spark-plugs than with one, especially in a very large cylinder. The size of the cylinder has much to do with it. A piece of paper lighted on two corners would not take so long to burn as if lit only on one corner. There would be two flames burning in two directions.

A MEMBER:—Might there not be some dead pockets?

PROFESSOR BAILEY:—I assume that neither spark-plug would be in dead gas. Assuming that both spark-plugs fire, it is borne out by tests that some increased power is obtained at high speeds. I have used the same device that Mr. Barthel mentioned for measuring lag. It worked very well indeed, and the effect was easy to see. I do not understand why he should have had so much trouble with the oscillograph.

MR. BARTHEL:—I went to the best engineers, trying to get a device that we could use in a demonstration to the court. They set up scientific apparatus but we found it was not practical. Some old-time coil-manufacturers finally set up the apparatus mentioned for me. It was better than anything I had used previously.

PROFESSOR BAILEY:—The oscillograph shows many things that this simple device would not, but for the one particular purpose stated the latter is very effective. I have used it to measure the lag of a single-spark system.

A MEMBER:—What effect has the width of the gap on the ignition?

(*Concluded on page* 607)

International Ball Bearing Standardization

By R. S. Burnett[1]

STANDARDIZATION of ball bearings in America received its first impetus in 1911 when the Society adopted the three series of metric annular ball bearings known as the light, medium and heavy series. These bearings followed the German standard sizes in their main dimensions as at that time Germany was the principal manufacturer of ball bearings and many of them had been imported into the United States. It was recognized that standardization would have to follow closely the practice which had become well established in the American industries.

A few years later, bearings larger in diameter were produced in a considerable volume, and as there were differences in the dimensions used by a number of American and European ball bearing manufacturers, standards were formulated and adopted by the Society in 1919 whereby the then existing annular bearings of the light and medium series were extended.

Another type also, referred to as double-row bearings, had been developed by an American manufacturer, the bores and diameters of these following the existing metric standards to allow of interchangeability, but inch widths being selected. Eventually other manufacturers produced this type of bearing, and in 1920 the present S. A. E. Standard Annular Ball Bearings extra wide type were adopted to harmonize the somewhat different dimensions used by the several manufacturers. Foreign-made bearings, if there were any, were so few as to have no influence on the American standard.

During the same period bearings smaller than the existing standard sizes were coming into common use in the conventional annular ring and cage and the so called "magneto" types. The magneto type was made in Germany and imported into the United States for some time, and then made in this country for American consumption. The need being recognized, in 1919 the magneto type was standardized as the "Separable" or open type, and in 1920 the conventional small annular type was standardized as the extra small series.

Another series had been used previously to a very limited extent in applications requiring very light-weight bearings. There was some thought of standardizing this series, but as its use was so limited and its manufacture considerably more difficult and expensive, it was felt that a standard was not in order. It does not seem likely that it will be standardized.

Although standardization of ball bearings up to at least the beginning of the World War followed the German standards very closely, no particular attempt was made to establish international standards. In 1917 it became evident that some international standards, particularly as to tolerances, should be adopted, especially for use in aircraft. An international conference was arranged for and participated in principally by the United States, Great Britain, France and Italy, the Society sending regularly delegated representatives. As a result a few changes were made in the standard ball bearing tolerances which had been in use in the United States.

Since the close of the war, requests have been made principally by Switzerland, for international ball bearing standardization. These requests were addressed to the American Engineering Standards Committee, a body recently organized for the purpose of coordinating American engineering standards in general, and to provide a suitable channel through which international standardization can be conducted. This Committee referred the requests to the Society of Automotive Engineers and the American Society of Mechanical Engineers, which became sponsors for American standards for ball bearings, and were delegated to make recommendations for international standards.

A sectional committee, organized by these two societies, held a meeting in New York City in December, 1920, for the purpose of establishing a program. A subcommittee was appointed to secure as complete data as possible from foreign countries in which ball bearings are manufactured. These data were eventually received from Great Britain, Sweden and Germany, and transmitted to the sectional committee, and a meeting of the subcommittee was held in New York City in March for the purpose of formulating recommendations for consideration by the Sectional Committee. Information received from the British Engineering Standards Association had been reviewed and checked with the American standards, the practice found to be practically the same for corresponding series and types. No information was received from France. A letter from the Bureau des Normes Du VSM. (Vereins Schweizerischer Maschinen-industrieller), Baden, Switzerland, was to the effect that its work had come to a standstill, but that the committee expected to resume work soon. A letter from the Association Belge de Standardisation advised that standardization of ball bearings had not been taken up by that committee, as imported bearings, principally from Sweden, were used exclusively in Belgium. Dr. Jaro Tomaides, secretary of the Osterreichischer Normenausschuss Für Industrie und Gewerbe, wrote that a committee had been organized in Austria for the purpose of standardizing ball bearings, but that as there was only one ball bearing factory in Austria, it had been decided to accept the German standards.

The data received from Germany showed in detail the standards proposed there for extra light, light, medium and heavy single-row ball bearings of the conventional and of a self-aligning supplementary outer-ring type, as well as for double-row bearings of light, medium and heavy series.

The subcommittee referred to consisted of O. R. Wikander, chairman; G. R. Bott, F. W. Gurney, F. G. Hughes, and C. M. Manly, vice-chairman of the sectional committee. Discussion of the series proposed by the Germans indicated that there is very little use for an extra light series in American practice; such bearings as are used here are imported, principally from Sweden. They are considered very unsatisfactory to manufacture and limited to use in special types of apparatus and classes of service. The subcommittee felt that if an international standard for them should be proposed, the Swedish dimensions ought to be preferred, but that it should be the policy of the subcommittee at this time to not make any recommendation for standardization beyond the limits of American experience.

Proposed Recommendations

The proposed German standard light series includes the same small diameter bearings as the S. A. E. Standard except that there are no 6 or 8-mm. (0.237 or 0.315-in.) bore sizes in the German proposal; the German series from 9-mm. (0.354-in.) bore up to and including 110-mm. (4.331-in.) bore coincides with the S. A. E. Standard. From 120-mm. (4.724-in.) bore upward, however, the German bearings are lighter than the S. A. E. Standard Light Series

[1] M.S.A.E.—Standards manager, Society of Automotive Engineers, New York City, and secretary, American Engineering Standards Committee's sectional committee on ball bearings.

Extra Large Type, the dimensions of which are more in proportion to those bearings having bores up to and including 110-mm. (4.331-in.). The proposed German standards specify less width, depth and capacity than the S. A. E. Standard. It is believed that the larger American dimensions, particularly the greater widths, are preferable. With regard to bearings exceeding in size those of the S. A. E. Standard Light Series, Extra Large Type, the subcommittee felt that the present field of use for such bearings is so small and knowledge as to their best proportions so limited that standardization of them should not be considered now.

The S. A. E. Standard Medium Series and the proposed German standard for bearings with bores from 10-mm. (0.394-in.) up to and including 95-mm. (3.741-in.) agree. The S. A. E. Standard bearings having bores from 100 to 210-mm. (3.937 to 8.268-in.) inclusive, do not agree with the proposed German standard, but have dimensions more in proportion to the bearings with bores up to 95-mm. (3.741-in.). The proposed German standards specify less width, depth, and capacity than the S. A. E. Medium Series. The subcommittee believed that the larger American dimensions, particularly the greater widths, are preferable. The present field of use for bearings exceeding in size those of the S. A. E. Medium Series, Extra Large Type, is so small and knowledge as to their best proportions so limited that it was considered unwise to standardize them at present.

With regard to the Heavy Series, there seems to be no necessity for a standard extending beyond the present S. A. E. Standard list of sizes, as the capacity of such larger bearings would be so much greater than that of the shafts on which they would be mounted as to make them impracticable. The present S. A. E. Standard series is used largely in this country in sizes having bores up to and including 100-mm. (3.937-in.) and when adopted was practically the same as the previous German standard.

The S. A. E. Standard and the proposed German standard for bearings having bores of from 17 to and including 85-mm. (0.669 to 3.348-in.) agree. The field for bearings larger than the S. A. E. Standard Heavy Series being small and knowledge as to their best proportions limited, standardization of them is not deemed desirable.

In the S. A. E. Standard Light, Medium and Heavy Series of the Wide Type, the bores and outside diameters follow the S. A. E. Standard Annular Ball Bearings of the Light, Medium and Heavy Series, the differences being in the widths. The Extra Wide Type, originated in America, is intended to take radial and considerably greater thrust loads than the single-row annular bearings. This series has become so thoroughly established that it is felt that any changes therein would not be practical.

The standard sizes Nos. 200 to 203 inclusive and Nos. 300 to 302 inclusive were not included in the recommendation of the subcommittee, serious doubt having arisen in the mind of the American users and manufacturers as to the desirability of increasing the width of these particular bearings. The standards which have been proposed by the German Committee for these wide bearings, are nearly all narrower than has been found satisfactory in American practice.

In the German proposals the corner radii advance by smaller increments than in the S. A. E. Standard and in many instances fractional millimeter radii are specified. The careful consideration given to corner radii when the ball-bearing standards were adopted and revised by the Society seems to warrant proposing the S. A. E. practice for the international standardization. Particular attention was called by the subcommittee to the fact that the minimum corner radii in the S. A. E. Standard denote the maximum fillets of shafts or housings that the bearings will clear, and that if the minimum corner radii are made smaller than specified in the S. A. E. Standards, bearings so dimensioned may not be interchangeable with the American standard bearings, due to possible fillet and bearings interferences. It is believed that larger fillets than are current in American practice are not required for strength of shafts and any increase in fillets and corresponding increase in corner radii of bearings, would reduce the actual pressure or seating area of the bearings, and perhaps entail an otherwise unnecessary increase in shoulder-height and raw-stock diameter of shafts.

The meeting of the Sectional Committee on Ball Bearings held in March was attended by the following members: Chairman W. R. Strickland, Vice-Chairman C. M. Manly, G. R. Bott, G. E. Greenleaf, F. W. Gurney, F. G. Hughes, G. E. Hulse, W. P. Kennedy, E. H. Lockwood, E. Nides, O. R. Wikander and Secretary R. S. Burnett. Dr. P. G. Agnew and T. C. D. Crow also were present. The absent members of the Sectional Committee were C. H. Day and C. Mills. Mr. Wikander, chairman of the subcommittee, presented its recommendations. The gradual development and adoption of existing foreign and American standards were reviewed and the basic principles upon which international standardization should be founded, and the influence upon international standards of present and probable future industrial conditions, discussed at considerable length. The unanimous decision was that inasmuch as the present S. A. E. Standards have become thoroughly established in American practice and to a large extent in Canada, Australia, India, China, Japan and Europe, any attempt to change them for the sake of international standardization would be unsuccessful and result in "paper" standards only, particularly in the United States. In view of the fact that the greatest volume of ball bearings is manufactured at present in the United States and used in American apparatus, and that the present standards were originally based upon the previous prevailing German standards, the sectional committee saw no reason for making changes in these standards at this time, the true value of standards depending obviously upon what is reduced to actual practice. Any attempt to change present practice would cause confusion.

Proposed International Ball Bearing Standards

After consideration of the report of the subcommittee and of what should be recommended for international standardization of ball bearings, the sectional committee voted unanimously to report to the American Engineering Standards Committee that

> After considering the matter of ball-bearing standards, it is the sense of the sectional committee that the American Engineering Standards Committee should recommend as international standards the existing S. A. E. Standards for Annular Ball Bearings, shown in the S. A. E. Handbook (revised edition), Vol. 1, pages C25 to C33 inclusive, with the exception of the Extra Wide Type, sizes Nos. 200 to 203 inclusive of the Light Series, and Nos. 300 to 302 inclusive of the Medium Series, shown on page C31, which sizes are under reconsideration regarding widths.

In view of the fact that the German national standardizing committee was planning to meet early in April for the purpose of acting on the proposed German ball bearings standards, the Sectional Committee on Ball Bearings recommended that the American Engineering Standards Committee send a cable to the German committee stating that the existing S. A. E. Ball Bearing Standards, with the exceptions referred to in the foregoing recommendation, are proposed for adoption as international standards.

It was further suggested that copies of the complete recommendations of the Sectional Committee be sent to the national standardizing committees of other countries with which the American Engineering Standards Committee has communicated with regard to standardization of ball bearings, and that Dr. Agnew, secretary of the American Engineering Standards Committee, confer with the chairmen of the foreign ball bearings standardizing committees in those countries whom he will see during his trip to Europe in April and May.

The work of the Society and the Sectional Committee on Ball Bearings is the most important concerted action that has been taken toward the establishment of unified ball bearing standards throughout the world.

Turbulence

By H. L. HORNING[1]

SEMI-ANNUAL MEETING PAPER *Illustrated with* DRAWINGS

GREAT interest has been shown in turbulence since the subject was revived a year ago. This paper is a collection of notes gathered from investigation of the subject in the literature on the development of internal-combustion engines and memoranda set down during a long series of tests. The paper includes a discussion of the physical and chemical aspects of the case and sets forth a working theory which has proved of value. Several methods of measuring turbulence are set forth.

HISTORICAL

Turbulence is one of the simplest things in ordinary life made mysterious by a name and lack of explanation. Turbulence is merely mixing to hasten the contact of two substances in a semi-liquid, liquid or gaseous state. Stirring of coffee to dissolve sugar is the most common daily use of turbulence. The whole art of ventilation is turbulence in a commercial form. The paddles on an ice-cream freezer are for the purpose of producing turbulence. German chemists dignified turbulence by a name. Le Chatalier and Mallard noted its effect in their classic investigation on flame propagation. Various other investigators have noted the increase in flame propagation due to turbulence. Wheeler and Mason note a doubled flame-velocity in a tube of 0.8-in. diameter between a quiescent mixture and one traveling at a rate of 9 in. per sec. along the same tube.

Prof. Bertram Hopkinson noted an increase in flame velocity in a closed vessel fitted with a fan. With a 9 to 1 air-gas mixture it took 0.13 sec. to attain the maximum pressure. With the fan running at 2000 r.p.m. the mixture came to the maximum pressure in 0.03 sec. At 4500 r.p.m. it took the mixture 0.02 sec. to attain maximum pressure. Sir Dugald Clerk in the same year, 1912, in which the Hopkinson experiments with closed vessels were performed, showed that where a 9 to 1 mixture was exploded on first compression the mixture attained a maximum pressure in 0.037 and 0.033 sec. in two separate explosions. When the mixture was ignited after it had been compressed three times, the turbulence being thus allowed to die down, the maximum pressure was attained in 0.092 and 0.078 sec. respectively; the rise in pressure in both cases being 2.5 times as fast with a turbulent flame. Clerk calls attention to the fact that the difference in the speed of pressure development between the first and second explosions is due to the more favorable location of the ignition, an important fact dealt with at length later in the paper. To Sir Dugald Clerk is probably due the credit of first recognizing that turbulence produces high indicated thermal efficiency at all speeds. Harry Ricardo has studied turbulence in later years and determined that with normal timing gas velocities through the intake-valves of from 130 to 160 ft. per sec. give the highest brake mean effective pressure, whereas velocities of from 160 to 180 ft. give the maximum brake thermal efficiency and velocities of from 180 to 200 ft. give the maximum indicated mean effective pressure. Ricardo has also made a study of combustion-chamber shapes and arrived at efficient shapes for various types of combustion-chamber. In England, France, Germany, Italy and the United States there has no doubt been a thorough study of turbulence in engines as there is a general use of gas velocities between fairly close limits in aeronautical engines produced in those countries. In this country Woodward, Lewis and Canby of E. I. Du Pont de Nemours & Co. have set forth their investigations in a very able paper which was recently published in THE JOURNAL.[2] The Bureau of Standards has done some good work in this connection but has not published its findings as yet. P. S. Tice has done some very creditable work in the investigation of turbulence by taking photographs of mixture-currents in glass models. This was described in THE JOURNAL.[3] It is pleasing to know that these photographs confirm the general course of the currents in cylinders shown.

Turbulence is any circulation in the mixture by which rapid mixing of the contents is effected during explosion. All forms of turbulence are of value in aiding orderly combustion. General currents are the most effective in distributing the flame and are the most easily maintained and economically produced. Eddy currents are less effective. These currents will be discussed in the section of this paper on methods of producing turbulence.

EFFECT OF TURBULENCE ON FLAME PROPAGATION

An examination of a large number of flame photographs indicates that there are four possible phases in the velocities of the flame in a tube of uniform cross-section, not all of which are apparent but which may be approximated in nearly all mixtures. The four phases through which the velocities pass are as follows: The flame traveling from *I* to *A*, Fig. 1, accelerates; and this phase is known as the phase of first acceleration. As the flame travels from *A* to *B*, it takes a uniform velocity; this phase is known as "the first phase of uniform velocity." As the flame travels from *B* to *C* it passes through a second acceleration, and is so known. The flame then travels from *C* to *D* attaining a high uniform velocity, and continues at this rate, which is known as "detonation." The use of a tube in the study of flame is merely a device for drawing out the process of ignition, and for developing these four phases of flame velocity. The tube tends to stabilize the conditions of quiescence and remove such artificial physical factors as stimulate the rate of reaction outside the kinetic energy of its constituents and outside temperature and pressure. Since the flame travels into an entirely fresh mixture undiluted by products of combustion, it increases in velocity rapidly due to increasing temperature and pressure, restrained only by constant area of the flame-crest, the chemical stability of the fuel and dissociation of the products of combustion.

[1] M.S.A.E.—Secretary and general manager, Waukesha Motor Co., Waukesha, Wis.

[2] See THE JOURNAL, March, 1921, p. 209.

[3] See THE JOURNAL, March, 1921, p. 282.

A tube has a limiting influence on the volume rate at which the mixture is consumed. In a tube the only way large volumes of mixture can be consumed in a unit time is by increasing the velocity of the flame. Where mixtures are contained in more compact chambers and the flame initiated at one point, the flame may travel out into the quiescent mixtures, which may happen in tubes of large diameter, and then recede or stop only to go forward again, causing a pulsating flame. All these manifestations seem to be a combination of increasing pressures, temperatures and the effects of the column-lengths and elasticity of gases. When the flame is started, a sound-wave is set up and travels to the nearest wall, reflects and passes through the mixture, producing visible effects in speeding up and slowing down the combustion.

For the practical man we may set forth some facts which seem fairly well established. The region *A-B*, Fig. 1, represents a condition of combustion which if it were possible to attain with homogeneity throughout the mixture would produce the highest thermal efficiency. The successive stages of *B-C* represent an increasing presence of too rapid combustion of some of the contents, with the resultant incandescence of solid carbon particles. These particles represent an increasing loss by direct radiation and no doubt this radiant heat affects the regions of unburned mixtures and accounts for a rapidly increasing reaction in these regions of flame. *B* is a point of low dissociation and may therefore symbolize the best compromise in practice between the controlling chemical and physical factors contributing to the highest thermal efficiency.

Phase *I-A* may be considered as the typical combustion had with lean mixtures and at low loads, and from a thermodynamic standpoint is characterized by a smooth sweet-running engine. Phase *A-B* represents the combustion of the most economical mixtures at loads at and under those giving maximum economy, provided there is no marked or incipient auto-ignition. This is at nearly full-load performance and with lean mixture of low-compression engines down to normal running. This phase is not characterized by a roughness in performance of the engine. Phase *B-C* is characteristic of the flame in an engine having a compression just low enough to avoid detonation at the most economical mixture, but running with a richer mixture. This may also be representative of an engine running when the compression-ratio is somewhat too high for available fuels. It is typical of the large class of cars built in the past for more volatile fuel. The condition is shown when running at full throttle either accelerating or at full load and particularly at slow speed. The action corresponding with this is a very rough performance and the effects can be easily felt as well as heard. Phase *C-D* is representative of very rough performance of an engine in which the compression-ratio is too high for the available fuels, the engine running at full load with a perfect mixture. The roughness is greatest at the speed of maximum torque, that is at relatively low speed.

The first phase is one in which the flame is blue. The second phase increases the intensity of color, which sometimes approaches green, indicating the very best and most efficient type of combustion. The third phase is one in which a yellow color is emitted from the flame, and the fourth phase is one in which the flame has a brilliant white appearance.

Inasmuch as the efficiency of combustion is represented by the velocities not exceeding *B*, the problem of combustion in internal-combustion engines resolves itself down to a resort to other means of increasing volume consumption than by flame velocity. The theory used and developed is the theory of maximum areas. This involves the simple geometrical fact that a volume is generated by an area sweeping through a given distance. In other words, in a quiescent mixture the most effective way of consuming the greatest volume of mixture in the shortest space of time is to provide a shape of chamber in which the flame surface or crest can spread out, developing at each successive advance an increasing area of contact with the unburned mixture.

In Fig. 2 at the upper left corner there is shown a conical-shaped chamber in which the lines drawn are the successive positions of the flame-crest at uniform intervals of time. In this form of chamber the area of the crest decreases very rapidly. In the lower left diagram, Fig. 2, is shown a conical chamber with ignition starting at *I*; the lines represent the advance of the flame in equal divisions of time. This form of chamber favors the development of an increasing area of the crest with each successive advance of the flame. It can be shown that the volume consumed in this form increases as the cube of the distance from the firing-point and since the distance traveled may vary in some mixtures roughly as the cube of the time, it is evident that great volumes can be consumed in very short intervals of time. This high rate of volume consumption is based on the assumption that the flame is traveling into unburned mixtures and does not take dissociation or dilution into consideration. If we make a figure of two cones, as in the upper right diagram of Fig. 2, starting the ignition at the point *I*, the flame will then travel out as shown and we will consume twice the volume of mixture in the same length of time.

Referring to the lower right-hand diagram, if we generate a sphere with a great number of cones, igniting the mixture at *I* at the center, we will consume the greatest possible volume in a given time with one ignition point. It has been found by Hopkinson in tests of explosive mixtures in vessels having approximately the form of a sphere that the rapidity of rise in pressure is maximum when the mixture is fired at the center, and minimum when the mixture is fired at one side. All these considerations have been based on a *quiescent* mixture. Many points of ignition afford means whereby great volumes of explosive mixture can be fired without reaching high unit-velocities of the flame at any region of the mixture. If we produce rapid enough circulation of the gases, that is sufficient turbulence, it is possible by igniting the gases at the point of greatest rapidity of movement to approach approximately the effect of a multitude of ignition points and, with a large number of "ignition points" so distributed throughout the mixture, to initiate numerous spheres of flame and therefore an infinite number of small velocities and rapidly increasing flame areas, and so consume the maximum volume of mixture in a unit of time without approaching the flame velocities of detonation. There are other considerations such as the area-to-volume ratio and the fact that spark-plugs have to be located at the outside of a sphere, considered as a possible combustion-chamber, but these need not be discussed here other than to state that, there being a cool layer of gas on the walls of the combustion-chamber, turbulence insures the consumption of a larger volume of gas in a given time by driving this cool surface gas off into the flame, replacing it with the products of combustion. In a sphere the volume of this layer of cool gas is at a minimum, while in side-pocket engines it is relatively greater and turbulence is of correspondingly greater importance.

Turbulence is merely a physical assistance to the process of chemical reaction by aiding the kinetic tendencies of one species of molecules to make contact with those other species with which they must unite under the conditions of temperature and pressure in the cylinder. The process of chemical reaction, of which combustion is one type, is a surface phenomenon. The modern conception of the constitution of the atom is that the outside layer of electrons is the one which gives the atom or molecule its chemical properties. Therefore, when we attain the maximum of flame-swept volume by adopting those shapes of combustion-chamber which will allow the most rapid increase of flame-crest area of quiescent or turbulent mixtures, we follow the most fundamental law of chemistry, that is, develop the maximum contact surface for reaction. In very slow combustions the reaction of hydrocarbons is in very many steps. As the reaction increases in rapidity, the chemical stages through which a unit-volume of mixture passes become more direct and it seems from all known considerations that the most thorough and best controlled combustions are those in which the combustion-chamber may be considered to be filled with a mixture comprising a large number of small volumes in which the initial and end stages of combustion are occurring at one time intermingled with the products of combustion and their dissociations. There should, therefore, be a general homogeneity throughout the mixture in temperature, pressure, chemical species and state of equilibrium, rather than a progressive reaction from one part of the mixture to the other. Turbulence tends toward the ideal condition in which the various reactions going on in any small section at any one time are somewhat typical of those in a section of similar size in any part of the mixture. This is the very antithesis of the conditions in a tube. On the other hand, turbulence can be controlled so as to cause a useful segregation in the mixture and it is thus possible to fire the mixture at its richest section while some parts may resist ignition. By this means it is possible to attain exceptional economies.

There are three surfaces in any combustion-chamber which inherently have a temperature above the average; the center of the piston, the center of the exhaust-valves and various points in the spark-plug. Turbulence tends to prevent the layers of gases over these points from reaching the point of auto-ignition. Where these layers occur in shallow pockets there is less opportunity for turbulence to keep the gases moving and the high temperature of the mixture at these sections must be kept in mind in locating spark points, as it has been proved by many investigators that the spark-plug should be placed in such a position as to ignite the hot portion of the mixture during the early stages of combustion when it is relatively cool rather than allow a flame traveling some distance to set this hot portion off by auto-ignition toward the latter part of combustion when temperatures and pressures are high and the maximum of radiant heat is flooding the combustion-chamber. When three high-temperature spots and a pocket claim the location of the spark-plug, it is necessary to compromise, giving preference to that locality which will set off the hot sections in a pocket first and then the mixtures of lower temperature. Generally speaking, after the pocket is taken care of, the spark-plug should be as near as possible to the greatest turbulence and the center of gravity of the mixture.

There are three spots where a spark-plug should not be placed; at any point remote from a pocket; at any point remote from a hot surface; at a point where it will be

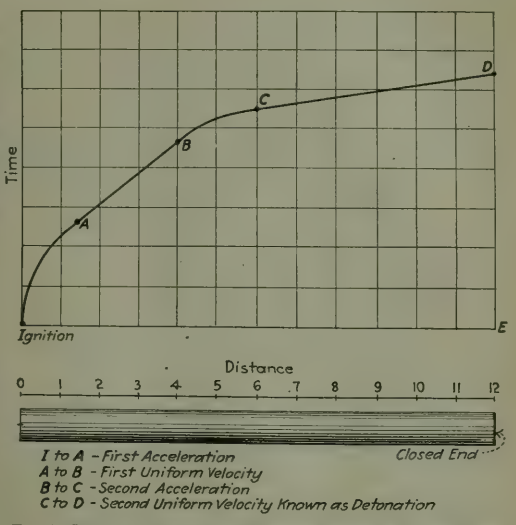

FIG. 1—DIAGRAM SHOWING THE VARIOUS STAGES IN FLAME PROPAGATION IN A TUBE HAVING A CLOSED END

washed by the exhaust and the pumping action of the rings.

In all natural processes the flow of energy is from the high to the lower levels. In a cylinder between the time of the spark and that of highest pressure several changes are going on. There is the drop of chemical energy in the form of active fuel and oxygen to the lower level of the products of combustion. There is the liberation of energy in the form of heat, light and electric energy during this process.

The undesirable characteristics of knock seem to come about because of vast differences in condition between relatively large masses of reacting gases in different parts of the cylinder. The process of combustion of the first portion of mixture is orderly because the layers of fresh gases are not close to their self-ignition temperature. There are great differences of temperature at any

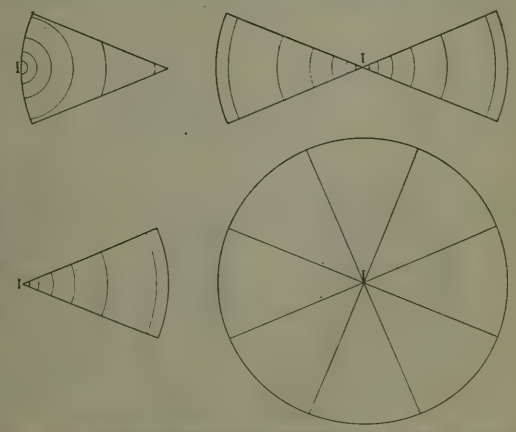

FIG. 2—DIAGRAM SHOWING THE INCREASE IN THE AREA OF THE FLAME-CREST IN DIFFERENT FORMS OF COMBUSTION-CHAMBER

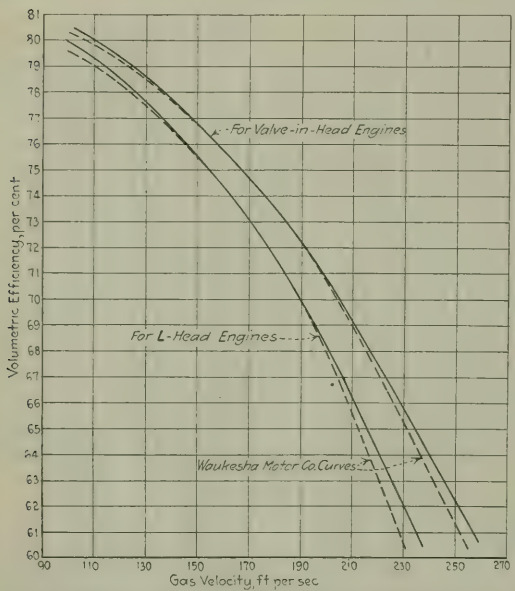

FIG. 3—CURVES OF INTAKE-GAS VELOCITY FOR VALVE-IN-HEAD AND L-HEAD ENGINES

instant during the combustion period. There exist great differences between the chemical species in different parts of the combustion-chamber during the combustion period. While rapidity of combustion is a desirable feature it is not desirable if it is attained by the precipitous processes represented by velocities at *B-C* and *C-D*, Fig. 1. The distinction to be kept in mind is large volumes consumed in unit time with limiting reaction velocities.

TWO METHODS OF PRODUCING TURBULENCE

Turbulence is produced by two fundamental methods based on the means by which the circulation is initiated. The first and most common method is by means of the intake-gas velocities. There is a fundamental defect in this method inasmuch as it depends on a high gas-velocity, which means relatively low volumetric-efficiency. Ricardo has worked out two curves of intake gas-velocity and volumetric efficiency (See Fig. 3). The lower curve is for L-head engines and the upper curve for valve-in-head engines. Our own curves are shown in dotted lines. It is common practice in England to treat the area of a valve as clear diameter x π x lift. It can be shown that this gives, with the average-shaped cam, an average

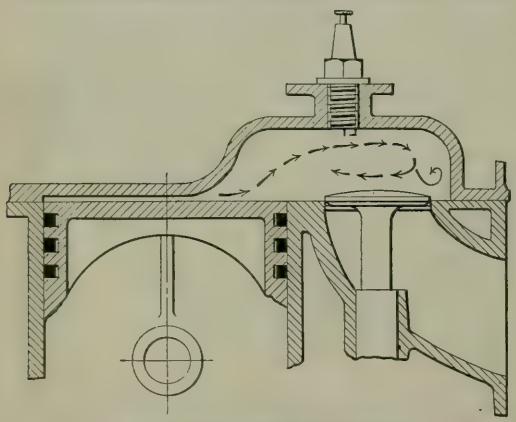

FIG. 4—CYLINDER DESIGNED BY RICARDO

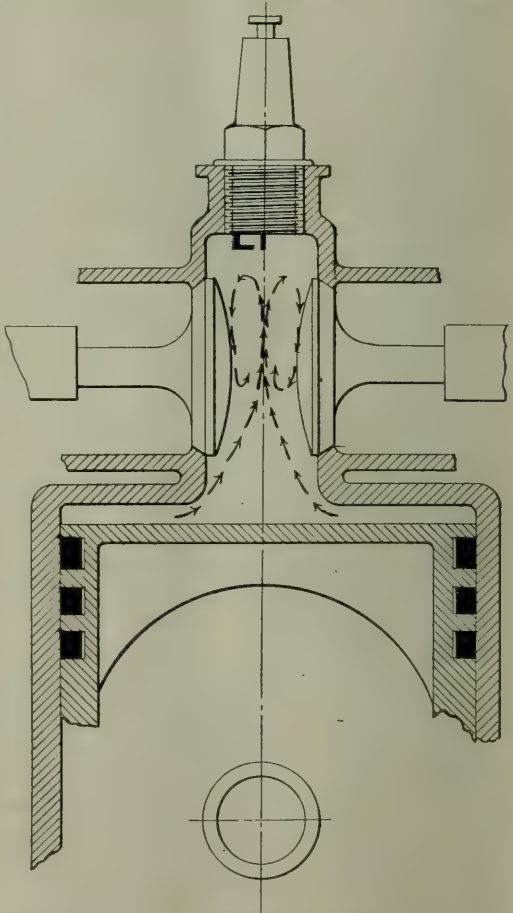

FIG. 5—DESIGN WHICH USED KEROSENE AS FUEL IN THE RICARDO TANK ENGINE

velocity value of practical form for use in calculating. We use this method in our work and all the curves shown are based on this understanding of gas velocity. It is obvious by this that since the maximum brake mean effective pressure lies between gas velocities of 130 and 160 lb., the best volumetric efficiencies for maximum brake mean effective pressure lie between 74.5 and 77.5 per cent for L-head engines and 75.5 and 79.0 per cent for valve-in-head engines. Since the highest indicated mean effective pressures lie between 180 and 200 lb., it is obvious the highest indicated mean effective pressures lie between 68.0 and 71.5 per cent volumetric efficiency for

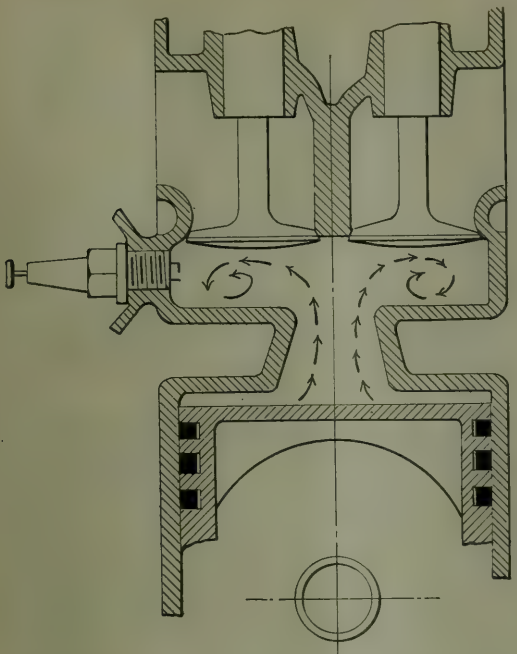

FIG. 6—A DESIGN OF A VALVE-IN-HEAD ENGINE WHICH PRODUCES TURBULENCE BY FORCING THE CONTENTS OF THE CYLINDER AT A HIGH VELOCITY THROUGH A VENTURI OF SMALL AREA INTO THE COMBUSTION-CHAMBER ON THE COMPRESSION STROKE

L-head engines and 70.5 and 73.5 for valve-in-head. The highest brake thermal efficiency comes close to and slightly above the velocities of maximum brake mean effective pressures.

Gas passages in the cylinder, which means the chamber shape, have a great influence on volumetric efficiency; so the figures above are a guide to diagnosis in experimental development. We have found, of course, that the velocities through the venturi in the carbureter have an important effect on indicated thermal efficiency and indicated mean effective pressure and they run from 420 to 520 ft. per sec. in Zenith and in Stromberg carbureters for maximum indicated mean effective pressure. So many factors enter into this that these results can be considered only as representing the performance of a fuel more volatile than commonly found and with a good aromatic

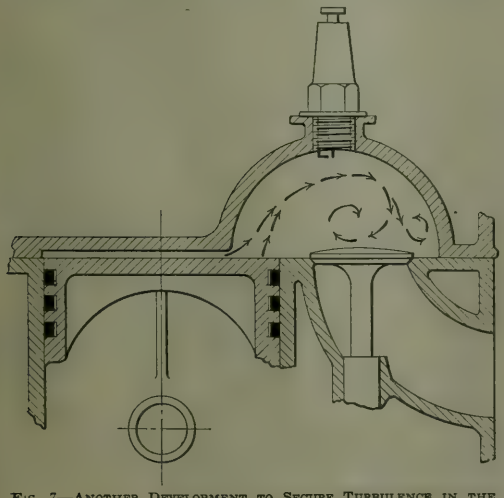

FIG. 7—ANOTHER DEVELOPMENT TO SECURE TURBULENCE IN THE VALVE-IN-HEAD ENGINE

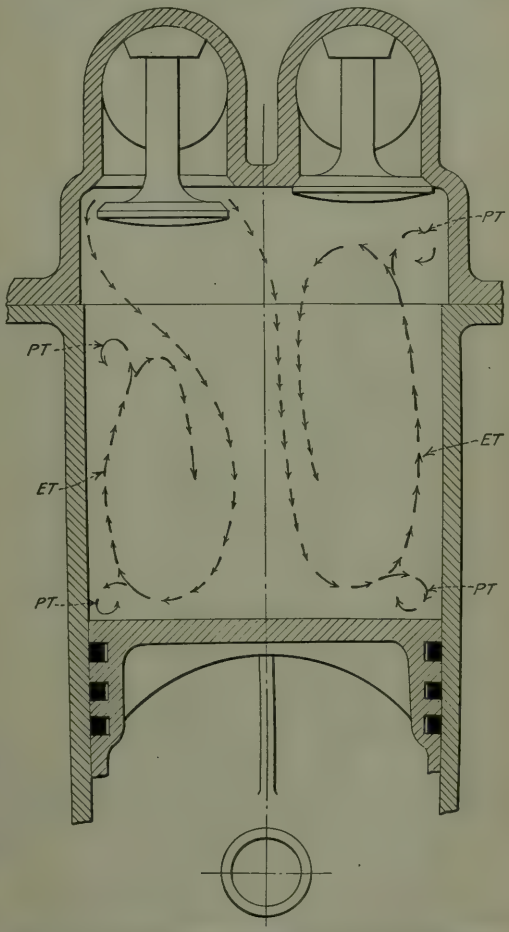

FIG. 8—DIAGRAMMATIC VIEW OF THE CYLINDER OF AN OVERHEAD-VALVE ENGINE SHOWING THE PATH OF THE MAJOR CURRENTS IN THE GAS

content. With heavier fuels higher velocities give better results, particularly in the manifolds and chokes.

Turbulence is produced primarily by the velocity of flow past the intake-valves during the suction stroke of the engine, and secondarily through the subsequent flow of the gases on the compression stroke. The flow through the intake-valve is at high velocity but discharging into a relatively large chamber the velocity tends to drop

abruptly due to the volume of the space and particularly to its shape. The turbulence which may be developed during the suction stroke is particularly susceptible to the dampening influences that generally exist during the compression stroke when the gas is being forced into a smaller space and at this period the persistency of turbulence is particularly subject to the influence of combustion-chamber shape. Whatever the natural direction of the gases, the shape of the head and all parts of the chamber should be such as to introduce no irregularities into the path. The flow during entry into the cylinder should induce a high velocity and symmetrical course of the gases after the valve is closed, this path merely lengthening or shortening, but keeping its general course when the piston is at its various positions. The energy available for turbulence is limited; hence the most regular and undisturbed paths tend to conserve the velocities. The moment of ignition is the moment of utmost importance. Whatever is done to produce or maintain turbulence must be done entirely in reference to the moment of ignition, for it is the turbulence at this instant which determines the distribution of flame throughout the cylinder.

In engines depending on intake gas-velocities for turbulence there is always a restricting influence in the compromise between high turbulence and volumetric efficiency, and this points to a more effective and convenient method of producing turbulence which will now be described. In Fig. 4 will be noted a design which is due to Ricardo. This design was developed by him after he had observed the very effective way in which the design shown in Fig. 5 handled kerosene in his tank engines with a relatively high compression without a knock. Ricardo stated to the author that it was almost impossible to make this engine knock on kerosene at compression-ratios of 4.75-1. It is obvious that in this design turbulence is set up at the proper moment through the velocity produced by the piston forcing almost the entire cylinder contents past the opening between the cylinder proper and the valve chamber. This opening need not be restricted to produce high initial velocities, for there is no intervening time for the turbulence to die out before the spark passes; in fact the design can be worked out so that the turbulence is reaching its very maximum when the spark passes. In this form the great problem is the flat section between the piston and the cylinder-head, which gives opportunity for the flame to run and knock from auto-ignition. From a turbulence standpoint this form is very effective and it can also be made so as to have a very favorable area-to-volume ratio, which is the coefficient of compactness. It is very favorable because of its compactness for an effective spark location. By making the combustion-chamber a hemisphere the most compact form possible is introduced.

There is still another way in which turbulence can be produced, namely, by forcing the contents of the cylinder at high velocity through a venturi of small area into the combustion-chamber on the compression stroke. Fig. 6 illustrates this for a valve-in-head engine and Fig. 4 for an L-head engine. Fig. 7 illustrates still another development. The fundamental difference between these methods and those met with in conventional systems is, first, that compression backed up by the piston furnishes a much more positive means for causing turbulence than the atmospheric pressure during the suction stroke and, second, gives an opportunity for producing a much more general movement of the gases and, third, turbulence occurs immediately before and during ignition, thus obviating its dying out. The defect of these systems is the increase in combustion-chamber area and the introduction of thin layers of gas at some points. So far as the main chamber is concerned there can be no detonation, but unless highly stable fuel is used there will be detonation in the shallow sections over the pistons. The main combustion-chambers of these forms have a relatively small area-to-volume ratio.

Turbulence produced by piston compressions is the most effective known for a given speed of engine. The gas must go through two passages, the valves and turbulence orifice, on the suction stroke; therefore, large areas at these points are advisable and permissible to sustain volumetric efficiency. However, because of the effectiveness of the method and the simplicity of flow and high velocities of the mixture at the moment of ignition, it is doubtful whether such high velocities of mixture through the turbulence orifice are needed as have proved necessary when producing turbulence by intake-gas velocity in normal types of combustion-chamber.

Figs. 8, 9 and 10 are marked *ET* to show points of effective turbulence. The paths shown indicate the major currents in the gas and should be provided for by design. They represent the greatest velocities and should involve a high percentage of the total mass of the mixture. The most effective turbulences are those involving the entire mass of the mixture in a general movement of highest velocity and along one simple course. This involves less loss in velocity and minimizes the eddies which generally may be considered as parasitic turbulence, marked *PT*. Since these eddies derive their energy from the main stream, they impede it. They are also of lower order of velocity and therefore less effective.

In engines of a design depending on intake-gas velocities for turbulence the proper combustion-chamber is that which follows most closely the lines of flow of the mixture. Such a form is illustrated in Fig. 11. Another form is shown in Fig. 12 in which the path of turbulence is indicated.

Characteristic Turbulence in Typical Cylinders

Fig. 8 shows diagrammatically the general currents in an overhead-valve engine of well known design. It is obvious that when the contents are compressed the contending currents will tend to wipe themselves out; this is the reason why overhead-valve engines take higher gas velocities to attain maximum brake mean effective pressure, brake thermal efficiency and indicated mean effective pressure. This type is the least effective from a turbulence standpoint. Fig. 9 shows an ordinary flat type of L combustion-chamber, the eddy currents illustrating how ineffective it will be and the large area-volume ratio makes it ineffective. This type will have low mean effective pressure and thermal efficiency. Fig. 10 is the usual T-head type which must be run at high speed with spark-plug located as shown to get sufficient turbulence for a high mean effective pressure and thermal efficiency.

Fig. 11 shows a form of combustion-chamber which Ricardo claims to have used on his design of the Mark Webber engine. While the reported results are remarkable we have never attained satisfactory results with the spark-plug placed over the piston as shown in his reports. In fact, we always had very severe knocking.

Fig. 12 is a type which has shown good results when the piston and head are like those illustrated in Fig. 11, but as shown here usually requires high speed to give sufficient turbulence for maximum mean effective pressure and thermal efficiency.

Fig. 4, Ricardo L-head type, gives a high turbulence and excellent brake mean effective pressure and thermal efficiency at all speeds and with a very small spark-advance.

Fig. 7, the Tyler type, in which the combustion-chamber is hemispherical in form, gives excellent results.

Fig. 5, Duesenberg type, is the same as that used in Ricardo's tank engine and the Bugatti aeronautic engine. It is very fine from the turbulence standpoint, gives high mean effective pressure and economy at all speeds and takes a relatively small spark-advance.

Fig. 6 shows a turbulent overhead-valve type in which the piston forces the cylinder contents into the combustion-chamber at high speed and thus makes it one of the best types from a turbulence standpoint.

Methods for Measuring Turbulence

The indicated mean effective pressure may be analyzed as consisting of the indicated mean effective pressure that would be attained if all the fuel-energy were available on the piston without loss multiplied by several efficiencies.

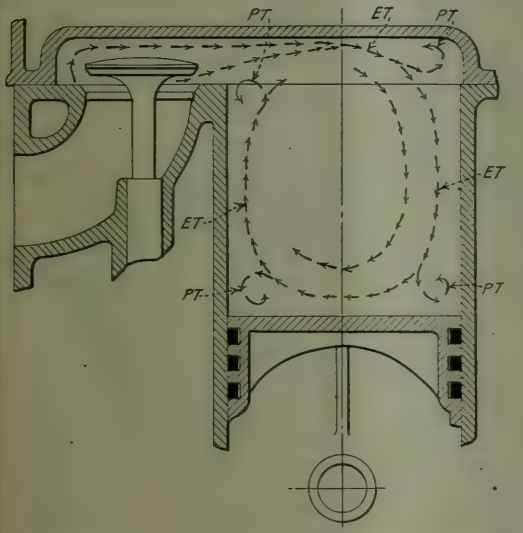

Fig. 9—An Ordinary Type of L-Head Combustion-Chamber

$$IMEP = Ae \times Ce \times Ve \times (D \times 12)$$

where

$IMEP$ = Indicated mean effective pressure
Ae = Air-cycle efficiency
Ce = Relative efficiency
Ve = Volumetric efficiency measured in pounds of air at standard temperature and pressure
D = Foot-pounds of energy per cubic inch of mixture
ITe = Indicated thermal efficiency or $Ae \times Ce$

The air-cycle efficiency values given in Fig. 13 are calculated from the formula $A_e = 1 - (1/r)^{0.4}$ where r is the ratio of compression. At a constant speed and with all the other factors such as the air-cycle and volumetric efficiencies and the energy content constant it is obvious that the relative efficiency which is obtained by dividing the indicated thermal efficiency by the air-cycle efficiency is a measure of the combustion efficiency and we use it as a means by which turbulence can be measured. Care must be taken in measuring the volumetric efficiency as one of the striking effects of combustion-chamber design is the effect on volumetric efficiency at various speeds, particularly when turbulence is produced by intake-gas velocities.

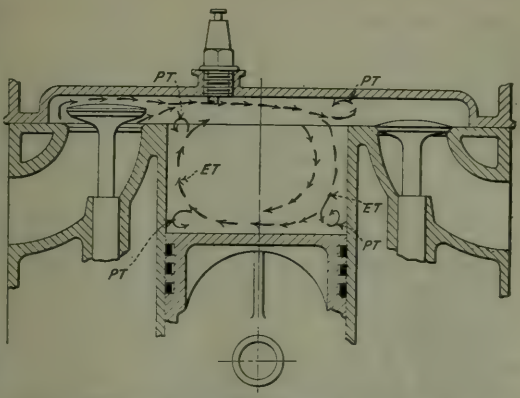

Fig. 10—The Usual T-Head Type Engine Which Must Be Run at High Speed to Get Sufficient Turbulence for a High Mean Effective Pressure and Thermal Efficiency

The ratio of the indicated thermal efficiency to the air-cycle efficiency is used abroad and is known generally as relative efficiency. The loss represented in this efficiency is due to four primary factors which may be outlined as follows, treating the losses as percentages of the air-cycle efficiencies:

(1) Loss due to increasing specific heat at higher temperatures, 17.5 per cent approximately. This must be corrected for the increased volume of the products of combustion, amounting to 3 per cent and reduces this loss to about 15.5 per cent
(2) Loss due to direct radiation, 13 per cent
(3) Loss due to the peak of the diagram, 1 per cent
(4) Loss due to the toe of the diagram, 2 per cent

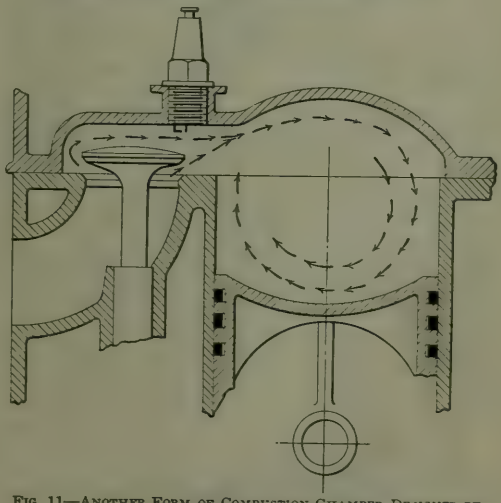

Fig. 11—Another Form of Combustion-Chamber Designed by Ricardo

These losses which total 31.5 per cent of the air-cycle efficiency and give a relative efficiency of 68.5 per cent tend to (*a*) decrease as size of engine increases and, as Ricardo has recently shown with one engine, (*b*) decrease with increased compression-ratio and (*c*) also decrease with increased speed. The reason for (*a*) seems to be the improvement due to the decreased direct heat-loss and a smaller surface-to-volume ratio. The reason for (*b*) seems to be the lower relative heat-loss with higher density and better combustion. The reason for (*c*) seems to be less direct heat-loss and increased combustion efficiency due to turbulence resulting from speed. The above losses may be considered very low and as applying to an engine with a unit cylinder displacement of 130 cu. in. per min., running at 1500 r.p.m. and with a 6½ to 1 compression-ratio.

While turbulence tends to cause an increase in the direct heat-loss, it decreases the dissociation losses and those due to after-burning are brought to a minimum. With a rapid combustion resulting from turbulence it may be expected that the ignition need not be advanced as far as usual. This is found to be true and the spark advance may, all other conditions being equal, be considered an excellent index to turbulence. That is to say, with the same compression-ratio, gas-velocity, fuel-to-air ratio and volumetric efficiency, the spark-advance in degrees may be considered inversely proportionate to the combustion efficiency.

We are gathering data for the purpose of working out a mathematical relationship between spark-advance and combustion efficiency, density and speed.

We have found it possible to attain with a combustion-chamber of L-head type, of the general shape shown in Fig. 11 with cast-iron walls, a relative efficiency of 64 per cent to air-cycle efficiency, as against 54 per cent with a shape approximately like that shown in Fig. 9. With a similar engine of valve-in-head type and at slightly higher compression-ratio, we secured on efficiency of 65 per cent to air-cycle efficiency under laboratory conditions with a gas-velocity of 170 ft. per sec. and a relative efficiency of 56 per cent with a speed of 110 ft. per sec. and slightly inferior carburetion.

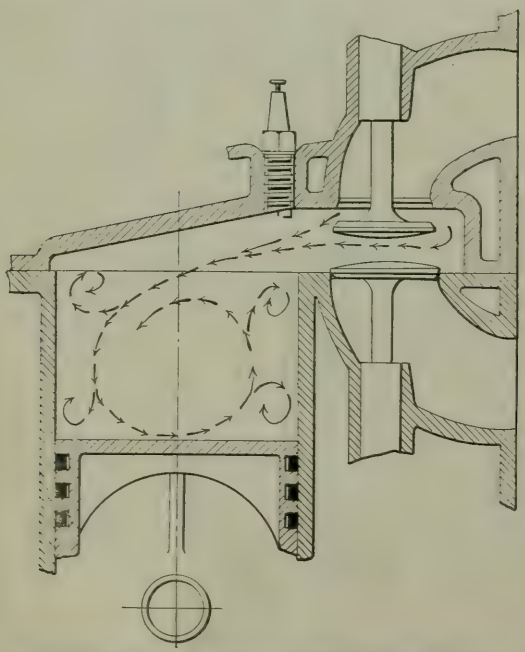

Fig. 12—High Speed Is Usually Required To Give Sufficient Turbulence for the Maximum Mean Effective Pressure and Thermal Efficiency in This Type

The relatively poor turbulence is markedly shown in the greater spark-advance of a valve-in-head engine and the high combustion efficiency due to turbulence is shown in the low spark-advance in forms of combustion-chamber in which the turbulence is highest, such as the high valve-pocket L-head design (See Figs. 5, 7 and 11).

We have found a spark-advance of 64 deg. necessary in a valve-in-head engine of 4 to 1 compression-ratio having a gas velocity of 110 ft. per sec. with a poor carburetion efficiency running at 1000 r.p.m. with a 15 to 1 air-to-fuel ratio.

We have found a spark-advance of only 11 deg. necessary on an L-head engine of the high valve-pocket design at the same speeds and conditions as specified for the valve-in-head engine above. In this case the relative efficiency was very high, offsetting a low compression-ratio.

Conclusion

It may be well to recall the effects of turbulence in performance.

(1) By developing high turbulence in a mixture, it is possible to drive off the surface layers of the combustion-chamber and thus force their full contents to contribute to the heat and pressure before the expansion-stroke commences. The fundamental conception of the constant-volume cycle is based on the working fluid receiving all its heat at constant-volume and instantaneously. Neither of these conditions is attainable for obvious practical reasons; however, the wide departure from this ideal with slow-burning mixtures, great spark-advance, low maximum pressures, bad after-burning during expansion, hot cooling-water and exhaust-pipes are marked symptoms of low turbulence, and result in low combustion-efficiency. Since the air-cycle efficiency is constant in any case, a high combustion-efficiency means a high thermal efficiency and since the indicated mean effective pressure is the product of the indicated thermal efficiency, the volumetric efficiency and the energy content turbulence is directly responsible for increased power

(2) Turbulence tends to hurry the combustion of the entire mixture volume without allowing any part to attain high flame-velocities manifested by pre-ignition, detonations or auto-ignitions within certain limits. These limits are difficult to express, there being no generally accepted scientific method for the purpose. Roughly speaking, the common fuels of 1915 and the spring of 1916 furnished by the Standard Oil Co. of Indiana were such as to allow a cylinder of the general form shown in Fig. 5 to run at a 4.6 to 1 compression-ratio without knock. Whereas, it is impossible to run with this shaped combustion-chamber with the present fuels without a knock at a compression-ratio of 3.7 to 1. With a combustion-chamber of the shape shown in Fig. 7 it is possible to run on the present fuels produced by the above-named company with a 4.2 to 1 compression-ratio without knock, whereas with kerosene it is necessary to keep down to a 3.9 to 1 compression-ratio if it is desired to run

without knock and without water-injection. These results are on a heavy-duty engine running at 1000 r.p.m., and with chemically correct mixture proportions. It is obvious that so far as compression-ratios are concerned we have not been able, under the above stated conditions, to offset entirely with combustion-chamber design the decline necessary in compression-ratios to prevent knocking with present fuels

(3) On kerosene-burning engines turbulence has made possible a combustion efficiency at fairly high compression-ratios without use of dopes, water or exhaust gases, giving an indicated thermal efficiency of 26 per cent and an indicated mean effective pressure of 80 lb. per sq. in. without special carbureter designs

(4) Since the fuel of 1915 allowed a compression-ratio of 4.6 to 1, its air-cycle efficiency was 45.8 per cent. The 1921 fuels permit a 3.7 to 1 compression-ratio with an air-cycle efficiency of 40 per cent; therefore the decline in fuel value shows a loss of 14 per cent in efficiency due to a necessary drop in compression with old styles of combustion-chamber. With new designs of combustion chamber, similar to those shown in Fig. 7 and 9, an air-cycle efficiency of 43.5 per cent is possible, cutting down the air-cycle loss due to fuel to 5 per cent. However, since 1916 we have improved the combustion efficiency from 54 per cent of the air-cycle efficiency to a possible 64, a gain of 18 per cent. Therefore, thanks to the turbulence, the fight against increasing end-points and unsaturated compounds shows an indicated thermal efficiency of 28.0 per cent with the 1921 fuel as compared with 24.6 per cent for that available in 1916

(5) Turbulence makes all high speeds possible by speeding up the flame propagation

(6) Turbulence makes high speeds possible without an excessive advance of the spark, and with high mean effective pressure and high thermal efficiency

(7) Due to turbulence, L-head engines of the form shown in Figs. 5 and 9 will be generally superior or at least equal to valve-head engines with respect to knocking, all other conditions being equal, including compression-ratio, mixture ratio and volumetric efficiency

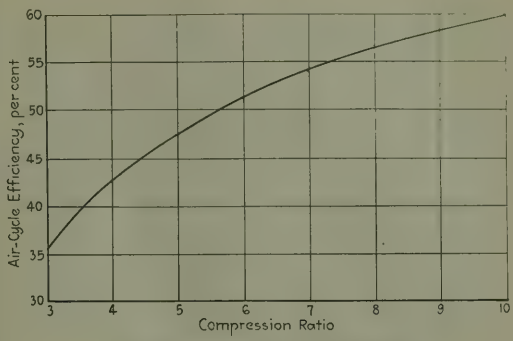

FIG. 13—CURVES OF AIR-CYCLE EFFICIENCY

(8) Turbulence has the effect of preventing knocking at a given speed equivalent to one-half a volume in compression-ratio, whereas dopes can improve the compression between three and four volumes, or an improvement of 7 per cent for turbulence against 33 per cent for dopes in air-cycle efficiency

(9) Turbulence is indispensable to efficient combustion with dopes or without dopes. It is possible to wipe out entirely all the advantage of increased compression allowable with dopes by low turbulence effects

(10) Flame propagation in internal-combustion chambers is influenced by the following factors in order of their importance

- (*a*) The chemical constitution of the fuel molecules
- (*b*) Temperature
- (*c*) Pressure
- (*d*) Turbulence
- (*e*) Mixture ratio
- (*f*) Compactness and shape of combustion-chamber
- (*g*) Location and number of points of ignition
- (*h*) Some property of the spark
- (*i*) Sound-waves in the mixture

RADIO CONTROL OF SHIPS

THE Iowa, it is thought, is the first ship that has been under complete radio or wireless control. There is an unconfirmed report that the Germans had a radio-controlled ship in the recent war. It is supposed to have been armed with a torpedo, but as far as known, no practical results were obtained from it. Before the war the Army was experimenting with radio-controlled torpedoes. It is reported that very satisfactory results were obtained. Under the Army system, torpedoes were launched and their course was directed by a wireless system from the shore. It is planned to use the largest torpedoes in connection with the coast defenses to resist the attack of the enemy fleet. It is understood that the Navy also is making some experiments with the radio-control of torpedoes from battleships.

The Bureau of Steam Engineering is using a radio-control in handling big battleships. It is obvious that this is a more complicated problem, as well as a spectacular achievement. The preliminary reports of the Iowa test are very gratifying. They indicate that it is largely a matter of perfecting the equipment to make the absolute control of the movement of one battleship from another possible. The Iowa was not only steered but her speed was effectively controlled by the commander of the Ohio. Three systems of radio were operated in the Iowa experiment. There was wireless "connection" with the machinery which directed the course of the ship, with the engine and with the pumps which regulated the control of the fire under the boilers and consequently the steam generation. The use of liquid fuel has made such radio-control possible. It would be impossible with a coal-burner. Of course, it will take time to perfect all of the features of the system, but so far no insurmountable difficulties have been met. One purpose of radio-control of a vessel is to provide the fleet with a battleship "in action" as a target. The great military objective, however, is the development of a system for war use. With it old battleships could be used more effectively in bottling up blockaded fleets in ports. With such a system the sinking of the Audacious in blockading the harbor of Zeebrugge in the last war would not have occasioned any loss of life and doubtless have been more successful. Neither would Hobson have been called upon to go into the harbor of Santiago under the Spanish guns.—E. B. Johns in *Sea Power*.

Addresses at the Farm Power Dinner

The Farm Power Meeting held at Columbus, Ohio, Feb. 10, 1921, terminated with a dinner attended by more than 200 members and guests, which was a satisfactory conclusion to this instructive session, especially with regard to the high character of thought expressed by the speakers. After appropriate remarks, President Beecroft introduced Fred Glover as toastmaster for the evening. Prof. J. B. Davidson, of Iowa State College, who has been identified prominently with the American Society of Agricultural Engineers, had as a subject The Engineer's Interest in Agriculture. L. J. Taber, master of the Ohio State Grange, delivered an address on The Rural Situation. President W. H. Stackhouse of the National Implement & Vehicle Association, spoke on the General Conditions of the Times.

ADDRESS OF PROF. J. B. DAVIDSON

AN eminent Canadian asserted several years ago in an address that there are three essential fundamental vocations of man. These three primary vocations are agriculture, meaning the production of food and raw materials for raiment and shelter; home-making, because the establishment and maintenance of civilization depend upon the home; and education, or the imparting to the coming generation of the experience of the past. It is worthwhile to consider this assertion and, I would like to have you, as engineers, consider some of the factors which make for the progress of this great industry, agriculture. We are all interested, for, if we would eat, we must either farm or have someone farm for us. When farmers quit buying tractors and automobiles, people in Detroit and elsewhere are not buying from other sections as much as they would otherwise buy; the people who work at making these machines quit buying clothing and other things because they have less work. Thus we find that the industry of agriculture is very vital. What, then, makes for progress in agriculture?

We have many persons who would solve the farmer's problem for him. Some suggest that the primary interest of agriculture is the maintenance of soil fertility. If this were true, we would find the highest state of agriculture in Korea, for instance, where they have maintained agriculture for 40 centuries; but the Koreans have grown larger crops from the land in the past than they do now and it cannot be true, for there we find almost the lowest standard of agriculture that can be found anywhere in the world. Again, there are those who insist that the primary essential to the progress of agriculture is the production of maximum crops from a unit area. If that were true, we would find on the European Continent the highest standard of agriculture, because Europeans produce more from an acre there than we do; yet we find there a low state of agriculture, indicated by the presence of peasantry. Some suggest that we are unfortunate because the rural population of the country is decreasing. The recent census shows that we have fewer farms in Iowa, one of the States which always stands near the lead in agricultural production, than we had 10 years ago. I assert that the percentage of rural population does not make for a high standard of agriculture because, if that were true, we would find the highest standard of agriculture in India, where 90 per cent of the people live on farms. With the 10-acre dry farm and the 5-acre irrigated farm a very low standard of agriculture is revealed by the standard of living. In California, where they undertook to put the Little Lander idea into effect, people settled on 2 acres or so and were not able to produce enough to afford them railroad-fare to get away. We do not need more people on the farms.

There are others who say that our farm land is running out. We have never had a shortage of food in the United States. The trouble now is that we have a surplus we cannot dispose of. The only time there was a shortage was when the Indians inhabited America; then, at times, there was famine. Last year I talked to a young Chinaman who informed me about the famine conditions in China. I attributed this to a lack of land, but he said that China has millions of acres of virgin land that have yet to be cultivated. This surprised me. I align myself with the new school of economics which insists that what we want is efficient agriculture. In using the word efficient, I refer, in part, to the social structure. The trend of our country depends upon the status of rural life. The health of the people on the farm is a factor. If they are to be efficient, they must be physically sound and strong.

Does capacity for production make for efficient agriculture? Regardless of the other factors, which are important, if we are to have a high standard of agriculture we must have a high capacity for production on the part of the individual. It must be possible for the individual farmer to produce a surplus. Most of the operations carried out on the farm are mechanical in nature. In growing a crop of wheat the operations of preparing the seed bed, planting the seed, harvesting the crop and transporting it to market, are all mechanical processes to which engineering principles and mechanical methods can be applied. The application of power has had a wonderful influence on production. It is possible now for a man to produce 30 times as much small grain today as he was able to produce in 1830. Along with the changes in production ability have come changes in wages and in the mental and physical conditions which surround the farm. We have passed through a development from hand to horsepower methods of farming and motor-tractor farming is here. It is now common to point out the enormous amount of power produced for agriculture by horses, tractors, steam engines and windmills. The aggregate is 25,000,000 to 30,000,000 hp., more than is used in all the manufacturing industries together. This is an inviting field for the engineer. It has been pointed out what an enormous sum would result in 1 yr. if we could effect a saving of 6 per cent in the plowing cost. Few engineers are studying as carefully as they should the economy that might be brought about in connection with the application of power to agriculture.

There are other factors in which the engineer is interested. It has been asserted that 42 per cent of the building construction in the United States is agricultural. Farmers are well housed themselves and they must house their farm animals; so, that is an inviting field for the engineer. There are 200,000,000 acres of land in this country that can be reclaimed by timber clearing, which represents an engineering project. There are 80,000,000 to 150,000,000 acres of land that can be reclaimed by drainage, and many areas can be reclaimed by irrigation. Some think that 150,000,000 acres of land will be reclaimed by irrigation. Many acres can be reclaimed by

following the principles we know about and bringing the land back into productivity by feeding the soil. Again, the engineer is interested in the sanitary equipment of the farm. I am speaking now of the water supply, the sewage disposal, the heating, lighting and ventilating systems of the farm which mean so much in comfort and convenience.

I take issue with the man who insists that there is no engineering in agriculture. It is one of the largest fields for the engineer. There is a great future ahead. I expect to see the day of larger tools, when a man can do even more than he is doing now on the farm. I expect we will have tractors that will go through the entire cycle of intertilled crop production, which is a great problem now. We will have cultivating mechanisms driven direct by the engine instead of having drag mechanisms going between the rows. We will have revolving cutters that will not only make it impossible for a weed to remain but reduce the soil to a good condition of till and provide a mulch. Perhaps we will synchronize machines and cultivate in between the hills. We will have the automatic plow and automatic combination implements. We will have the truck with the corn-husking attachment on the side.

I am rather inclined to think that we are not in a position to do these things at once, and to develop equipment as fast as might be, because manufacturers make their product to sell at a profit and there is not much profit in experimental work. But we shall see a great development in this connection very soon, because the farmer is thinking about getting more for his product and reducing the cost of it. This is a matter worthy of attention. In a survey made in Iowa recently to determine the cost of producing corn, it was found that on 60 farms the farmers use 3 hr. of labor to plow the acre for the corn. With a team and a gang-plow that time can be reduced to 2 hr.; I have done better than that myself. With a tractor the time can be reduced to 1 hr. or less. With hay 5 hr. of human labor was required. In Iowa, it requires 10 hr. per acre to harvest. Regular practice is not anywhere near the best practice.

Engineering, as related to agriculture, has not developed faster because engineering has developed on a professional basis; it has been supported by fee. The farmer has not been able to pay the engineer the fee necessary to support him. It is only in connection with commercial or public organizations that the engineer who is devoting his entire time to the agricultural industry is able to maintain himself. It has been suggested that there might be some conflict between the interests of the automotive and the agricultural engineers, but I think there should be no conflict. Where those interests conflict, there should be the fullest cooperation. It is to our particular interest to see to it that the profession of agricultural engineering develops, because agricultural engineering will be a factor in enabling the farmer to produce a larger surplus. Out of the surplus that the farmer produces he is enabled to build a better home, to equip it with modern conveniences and to provide all manner of mechanical farm equipment. We should have a capacity plan of production in agriculture which will enable the farmer to buy.

ADDRESS OF L. J. TABER

THE rural situation is the largest subject that could be assigned to any speaker just now, so I desire to bring to you with frankness and fairness a vision from the sunshine and the fresh air of the open country, because I am proud to say that every interest I have primarily is in agricultural land or cooperative farm enterprises. I am glad to talk to this audience of engineers because the triumphs of the century that have changed barbarism to civilization have in some degree been the triumphs of the engineer. War has become a problem of the engineer. Agriculture is becoming rapidly a problem of the engineer. Automotive engineers can do more for the future of rural life and more for civilization than any other equal number of men, I might almost say, in this country. The progress of agriculture appears amazing when we realize that it is measured within the short span of the life of men here present; and none of us are very old, although I see before me men who in their automotive thoughtfulness have thought every hair off of their heads and others whose heads the working of their gray matter has whitened. During the thousands of years since the slaves of Pharaoh built the pyramids, the methods of producing the food supply of the human family have been almost without progress or change. It was the task of American engineering and manufacturing genius to develop the marvelous resources of mechanical power, apply this power to the solution of the problems of the farm and make agricultural progress possible. Reviewing the situation as we find it in the country, it is clear that power-driven farm machinery and the prosperity of agriculture are so interlocked that they are inseparable.

There has never been in the Buckeye State any of the radicalism that has marked the steps of agriculture in some States of this Nation, and there will be none unless the financial and manufacturing forces of America are blind to conditions that are developing in rural life. We hear much of deflation. I enter into no discussion of economics in that regard. I know conditions are dark nationally and internationally. All should realize that fact, but there is no need for pessimism. The subject of deflation reminds us of the much heralded farmers' strike. I heard a leader of finance make the statement that the rapid decline in prices would have splendid advantage in that it would bring to us a reduced cost of living. The cost of living has been unnecessarily, arbitrarily and unreasonably high, and the burden has fallen on those who do not live in the country. The deflation of agricultural prices which is being heralded in the industrial centers will be short-lived. The American farmer purchases about 45 per cent of the manufactured articles of this country that are not exported. Deflation is necessary. The largest financial institution in Ohio states in a recent bulletin that the decline in the last 6 months of the farm values of America is 56 per cent. The so-called farmers' strike is not so much a strike as it is the natural operation of immutable laws. The dollar of the farmer has changed in value from the 100 cents of one year ago to the 44 cents of today. It is not entirely a strike; it is simply the working out of conditions. It is true that the farmer is not buying and may not buy for a period, but I believe an adjustment is taking place which will bring to us better conditions in this regard.

If the farmer is without the things which are essential to efficient and economic production, it may be possible for him to do without fertilizer for one crop, but it would not be economical. It might be possible for him to patch up his old machinery, but it would be false economy in view of the existing labor and material shortage. The main thing which is wrong is that those in the country and in the industries at large do not understand each

other as they should. There is no more valuable service that can be rendered today than the furthering of a better understanding among the farmers, the men who manufacture the tools and the engineers who shorten the farmer's labor and increase his efficiency. When those forces understand each other better, they will realize that the prosperity of the one is bound up in that of the other; that by cooperation and mutual agreement they can make the progress which is so necessary for industry and for agriculture.

The automotive engineers and the tractor builders are friends of ours because they have supplied mechanical agencies that tend to keep the boys on the farms, but we must insist upon a higher standard upon the farm along all lines. A farmer told me last summer that to keep his son from leaving the farm he bought a tractor, a manure-spreader, a mowing-machine attachment and a new binder. He said the boy had no desire to go away then. I stayed for supper and found that farmer's wife had to carry in water 100 ft. from a well. Our farming has been done only partially. We must insist on a higher standard of living in the country. The farmer must have sufficient reward to put into his farm home a water system, the vacuum cleaner, the power washer and all the conveniences and attractions that can be found in any other home. When we discuss the future of modern agriculture and power farming, we must think not only of the mechanical part that relates to the farm and to production, but realize that agriculture must be sufficiently remunerative to keep the boys on the farm and hold the girls there as well.

Quantity production is essential, but there will be no permanent prosperity in rural life until we realize that marketing is a function that must be given attention along with production. This may not appear economically sound to the trained engineer, but we insist that no amount of increased production will bring enduring prosperity to agriculture if the marketing problems of the farmer are neglected.

The farmer recognizes his need for good churches and schools and that they are the foundation of good agriculture. He understands that he must have as many commodity organizations as there are commodities to be distributed, such as milk, wool and other distributing organizations. The American farmer and the public have failed to appreciate that the farmer must take a larger share in the conduct of his own affairs. In connection with community organizations that stimulate the social, the educational and the moral life, develop leadership and train people to serve agriculture, we must have commodity and business organizations to look after the larger machinery of agriculture and to secure for the American farmer proper cooperative distribution machinery. There is no socialism, radicalism or communism on the farm. The American farmer desires to become a business man as well as a producer. He has no desire at all to interfere with any of the established methods. Cooperation is here to stay. We are just in the infancy of the greatest organization movement relating to agriculture ever known and it cannot be stopped.

The farmer has no desire for the elimination of the middleman or to control anything but the products of his own toil. He has no desire for a trust, or for favors that are not granted freely to anyone else, but he is insisting that modern agriculture be equipped through organization, education and cooperatve machinery, so that it will be possible for him to take into his own hands the conduct of his own affairs as any other business man would do. The American farmer is preparing to put his own money into his own business. He wishes to shorten the route between the consumer and the producer, not so that the consumer will pay more, but so that the farmer will receive more for his products. The automotive engineer, the tractor builder and the implement dealer will receive more then, and so will society, because better standards will be set up in the country and the equipment that is necessary to maintain those standards will be forthcoming.

Those of the automotive industry who are serving agriculture are serving civilization by improving machinery and by lightening the toil of the men in the country. We are friends and your prosperity is our prosperity. The man in the country is neither suspicious nor critical, although just now he is somewhat pessimistic. But you are going to find the farmer in the market again and, as he begins to liquidate, you will find him putting his money into your pockets, for his own and for your own good.

I cannot conclude without picturing the day when we shall have the independent educated farmers organized. The right kind of organization is for your good and for the good of agriculture and you cannot stop it. Farmers love the institutions of the Republic as their ancestors loved them, realize that there are certain lines beyond which they cannot go and comprehend the responsibilities, rights and duties of all in a community interest. God never made a written contract between you and me, but there is one just the same. It is the divine law. Its slow-working process has left me upon the farm and it has placed you in manufacturing establishments. There is a contract between you and me in that I am to stay on the farm and produce the food, and you are to build the machinery. We are going to work, realizing that this bond of fellowship cannot be dissolved. Some men must stay in the country and some must stay in the town; some must produce tractors, clothing and food, and some must take care of the transportation and distribution. The great plan of God provides a place for us all and, when we fill that place, we will make this country of ours not only a better place in which to farm, but a better place in which to operate a business and a better place in which to live.

ADDRESS OF W. H. STACKHOUSE

THE farm-operating equipment industry and the basic industry of agriculture are so thoroughly intermingled that I find myself unable to discuss the one to the disregard of the other. Realizing the absolute interdependence existing between these industries, the National Implement & Vehicle Association, which represents 93 per cent of the entire output of farm implements in the country, took the initiative some time ago of periodically having informal conferences with the officers of the principal national organizations of farmers. I am a firm believer in organization and the absolute propriety as well as the necessity for organization along sound economic and constructive lines by the farmer, the manufacturer and all other different groups of commerce. When I refer to business I use the term in a sufficiently comprehensive form to include the farmer. I regard him as the best business man in the United States from the standpoint of commercial capability. Very logically and inevitably, the business of this country is undergoing a more or less serious depression that will be more or less prolonged. That is logical because the entire population of this coun-

try has been on a great joy ride since the armistice, but that period has about terminated.

Some illuminating statistics have been prepared and published periodically by the United States Department of Agriculture. In 1820, 95 per cent of the population of this country lived on the farms; in 1920 only 49 per cent of the population was rural. Under the conditions prevailing in 1850 it would take one man over 570,000,000 days to raise the crops of 1920, but under the conditions prevailing in 1920 that one man could raise the crops of 1920 in a trifle over 119,000,000 days. This is a gain of 79 per cent, due almost wholly to the advent of modern farm equipment, intelligently and economically utilized. That constitutes a real achievement in the evolution of agriculture in this country. The major contribution in that achievement belongs to the farm-operation-equipment industry.

It would be folly to deny that this business depression has not affected the farmer tremendously; and it affects adversely every other industry. The only distinction I make in the discussion of this problem between the agricultural industry and all others is that agriculture is basic. The problem before us all today is purely one of economics and I propose to discuss it solely from that standpoint. It is not a problem that can be solved from the standpoint of sentiment. When it comes to a comprehensive analysis of a profound economic problem simply for the purpose of arriving at a solution, that is the time to disregard all sentiment to arrive at an intelligent and approximately an accurate solution.

The most recent statistics regarding crop production and values for the year 1920 place the value of all farm products at some $19,856,000,000, or a trifle over $5,000,000,000 below the value of these products during 1919. I think that the farmer has not lost $5,000,000,000, although it is true he has sustained a book loss. Book losses and actual losses are frequently vastly different things. Whether or not the farmer, as such, has sustained a loss and what his net loss is, it is impossible for him to determine until he has liquidated his holdings, just as in the case of the manufacturer.

This total valuation of farm products at $19,856,000,000 is 100 per cent more than the value of the total products of 1914, the last prewar year. The total value of farm crops during 1920, as distinguished from the more comprehensive term "farm products," was about $11,145,000,000. That is over 80 per cent greater than the value of the crops raised during either 1914 or 1913, and the latter was the banner year up to that time. The value of all animals and animal products raised on the farm during 1920 was 132 per cent greater than during 1914, and that was the banner year at that time. The value of those animal products in 1914 approximated $3,700,000,000; in 1920 the value was $8,700,000,000. The concluding statement is that the value of all farm crops during 1920 was 2 per cent more than the average value during the 5-year war period of 1914 to 1918 inclusive. I quote these statistics to correct the misapprehension many of us have had, due to inaccurate statements regarding these same matters that are made by the unthinking and the uninformed. I submit that the farmers of the United States still unmistakably possess a tremendous buying power. The farmer never has been a profiteer or a striker, and I predict that he never will be.

With further reference to the close interdependence existing between the basic industry of agriculture and the farm-implement industry, let us consider how manufacturers have deported themselves with reference to the prices charged the farmers. Let us see whether they have been culpable of anything that would justify adverse criticism of their conduct in relation to the ultimate consumer as well as to the primary producer, the farmer. The Federal Trade Commission at Washington recently completed a 2-year investigation of the farm-implement industry and stated that in the 6-year period from 1913 to 1918 inclusive the average price of farm implements increased 72 per cent; the average price of all other commodities sold to the farmer, which would affect his costs and profits, advanced 97 per cent; and the average price of farm products of all kinds had increased 118 per cent. These statistics have since been extended up to and including 1920 by a company that is not in the farm-implement business. They show that for the 8-year period from 1913 to 1920 farm implements had increased in price 78 per cent; farm products, 112 per cent; labor, 115 per cent; and all other commodities, 144 per cent. That indicates unquestionably the conservative policy that has been pursued in the matter of price by the manufacturers of farm implements in this country in the past 8 years.

In further connection with this matter, let us consider the relative advance in prices in the same period of the principal commodities entering into the construction of farm implements. I will give statistics which have been compiled by our Association from one of the largest industrial communities in the United States where the principal product is farm implements. We find that in this period steel bars increased 106 per cent; sheet steel, 147 per cent; old rails, 217 per cent; soft-center steel, 144 per cent; pig iron, 218 per cent, although today it is 115 per cent higher than then; malleable castings, 200 per cent; and yellow pine, 175 per cent. Labor increased over 125 per cent and, since 1914, freight rates have increased 101 per cent.

Still holding to the substance of my theme that not only the farmer but every other commercial industry in this country is more or less adversely and seriously affected by the business depression, we find from recent statistics by Dun and Bradstreet that we had 8881 commercial failures in this country in 1920, representing a total of $295,000,000, or $100,000,000 greater than in 1916, and that the commercial mortality in January 1921 is the highest we have had in some 8 or 10 years for that month. In addition, one has only to look to South Dakota to learn that, as the result of practising unsound business methods in violation of all economic rules, some 27 banks failed in the past 4 months. In the last few years it required very little talent, relatively speaking, to be a successful farmer or manufacturer in this country. Our sales were made automatically and likewise our collections. Almost anyone can be a thoughtless optimist in times of that kind. It tests the ability, the character and the mettle of real men to be constructive optimists in times like the present. Through intelligent and persistent cooperation we can reduce the effect of this period of depression to a minimum. That is the only way in which it can be done. We should cooperate most aggressively with the American farmer to see that he is accorded preferential treatment with reference to obtaining the proper amount of financial assistance for his legitimate requirements. Aside from that and treating the farmer as fairly and observing the same rules of ethics that every sound and honorable business man should observe, are we not obliged to share proportionately in the vicissitudes of commercial life in this country and in the world, just as at other times we share disproportionately in the unusual

prosperity of this country and of the world? It seems to me that this is perfectly sound and something we should insist upon.

The greatest misconception has existed in many minds in this country and particularly in the case of a great many farmers as to the propriety of the existing prices of the farm-implement industry as a whole. We are fully aware of the shrinkage in value of farm products. But when, under the powerful stimulus of a great war, it is impossible for us to gratify the demand for foodstuffs and the machinery and equipment required to produce them in maximum quantities, are we not aware that advances in prices do not occur with scientific precision or commence simultaneously, any more than they advance proportionately? The statistics I have quoted emphasize the correctness of that statement. Is it not true equally that, when the turn comes, as it has come, and during the more or less chaotic conditions surrounding a reconstruction period, prices do not decline simultaneously, proportionately, or with scientific accuracy? It requires time, and it is an uncomfortable time, to reach what may be termed a normal basis. Then the prices of all the different commodities strike their respective levels which are never, should not be and never will be uniform, because all things are not worth the same amount and nobody contends that they are. That is precisely the period we are passing through at present. So, let us not forget that, since the price of farm implements did not advance proportionately or simultaneously with that of all the other products, the price will not come down with scientific accuracy.

With reference to a reduction in manufacturers' prices, that time is coming. It will come just as soon as the replacement cost of the manufacturers' product is reduced. I have been asked why the manufacturer does not reduce his price right now and take his loss. If the proposition were as simple as that, he would gladly do it. The manufacturer will sustain his loss. Through the war period and since the armistice the average net profit has been 10 per cent or less on the investment of the implement manufacturer. If I am not mistaken that 10 per cent, minus, will disappear entirely this year when he does sustain his loss on his high-priced inventory. If I reduced prices today 25 per cent, replaced at the higher cost, sold again at the same 25-per cent reduction and replaced again, and all other manufacturers did the same, one-half of us would be in the sheriff's hands within 6 months, as well as two-thirds of the dealers, as would the same percentage of any group of business men. The farmer should not go on a buying strike. This does not mean that he should be silly enough to buy something he does not need, but if some machinery manufacturer produces a tool that costs $10,000 and the farmer can use it economically and reduce his production cost to a minimum, he cannot afford not to buy that tool. If ever a time existed when he should utilize mechanical equipment to produce at a minimum, it is now. We certainly expect him to buy exactly the equipment that will adequately enable him to produce at a minimum cost, but no more than that. The law of supply and demand is in operation. The manufacturer will have to observe that inexorable law, as well as everyone else.

With regard to the unnecessary multiplicity of types of machinery for farm operation, I would say that our association is represented on the Committee of Agricultural Equipment Standards, as are also the Society of Automotive Engineers and the American Society of Agricultural Engineers. As a result of effective cooperation, we ascertained that last year alone we saved the American farmer $10,000,000 by selling implements to him for $10,000,000 less than we could have afforded to sell them had it not been for the campaign toward intelligent elimination. This is an activity that redounds almost entirely to the benefit of the farmer, and indirectly to the benefit of the manufacturer in that it makes the farmer a better customer. One other activity was initiated by our Association in 1917, which was approved by the Government. We instituted repair-week campaigns in January 1918 and have maintained that activity ever since. In February, March and April of this year we divided the entire country into three zones and devoted a week in each zone to advocating to the American farmer that he repair his old machinery and utilize it in preference to buying new machinery.

In conclusion, although the sun is not shining just now, figuratively speaking, we will solve all our problems together and through cooperation. History shows unmistakably that when intricate, irritating and vexatious problems have confronted us we have never failed to find sound, practical and correct solutions of them. That will be the case in this period of business depression which will terminate quickly proportionately as the farmer, the manufacturer, the merchant and the banker cooperate along sound, economic, constructive business lines.

AMERICAN TECHNICAL SCHOOLS

THE first American technical school, Rensselaer Polytechnic Institute, was founded in 1824. This was the only school of its kind for nearly a quarter of a century, until 1847, when Harvard established the Lawrence Scientific School and Yale, the Sheffield Scientific School. The University of Michigan also established in the same year a course in civil engineering. Until the Civil War there were no other schools of this character. In 1862, Congress enacted the Morrill Land Grant Act providing, through grants of public lands, for the endowment of schools to teach agriculture and the mechanic arts. This act immediately stimulated the establishment of technical schools and from a total of 4 in 1860 the number increased to 70 by 1872 and to 85 by 1880. There are now 126 institutions providing engineering courses, 46 of which are land-grant colleges operating under the provisions of the Morrill Land Grant Act. In addition to these, there are 43 other institutions that give some engineering instruction.—T. H. MacDonald.

Aerial Transportation of the Immediate Future

By Ralph H. Upson[1]

Annual Meeting Paper *Illustrated with* Charts

THE economics of a business is usually worked out after the business in question has become well established. The success of the railroad or the automobile has been necessary to encourage the formation of college courses for the study of them, which is extremely valuable, although it comes too late to be of much service in the organization of the original plan. I am trying to outline in advance some of the factors in the fundamental economics of air transportation which must be recognized even in its original plan and conception, especially in regard to the airship, which requires such a large outlay of capital at the start if we are to expect much success. The extent to which investors will place money in plans of this kind, the extent to which communities will develop landing-fields and the extent to which Congress can be prevailed upon to furnish what aid may be necessary all depend upon the whole subject working out as a real economic factor.

We have three recognized forms of transportation worth mentioning at present; railroad, steamship and motor truck. Of these I would call the railroad and steamship primary and the motor truck secondary, the last named being used for more special purposes. As to the new forms of transportation, the airplane and the airship, in the last analysis it must be left to the investors to decide how far to go. Three questions are typical of the average investor in this connection, and they are worth noting at the start. In considering a new transportation vehicle the first question is, "Will it work?" The attitude expressed in this question is now nearly outgrown. It was formerly the one formula for inventors and investors alike, but the matter of whether an invention will "work" is left entirely now to the men who have studied the subject and proved that they know how to make their inventions work. The next question is somewhat more imminent. We are not yet past the stage where we ask, "Is it safe?" Many of us base most of our calculations on that point. But I am sure that this matter also soon will be left in the hands of men who have proved that they know how to make air-travel safe, with much the same confidence. But, because it is a point often raised at present, it is well to take it into consideration. Safety is relative. There is no such thing as absolute safety; but the relativity of safety must be applied in the right direction. There are certain apologists who argue that we should expect danger in aircraft, that we cannot get something for nothing, that we are getting extra speed and that we should expect to take somewhat more risk. I distinctly disagree with any such sentiment. In fact, all reasonable consistent analysis seems to indicate exactly the contrary; that the more speed we have, the more important the matter of safety is. This will be clear, as applied to passengers, from just one consideration. If the time of a business man is of the utmost value and he is willing to pay the fares which will be required for air-travel, to pay extra for increased speed, he also will value his safety that much the more. He will be unwilling to use a transportation vehicle, no matter how fast, if he must risk his life in the attempt. So, I insist that in aviation work it is not a matter of sacrificing safety to get speed; there must always be speed *and* safety. As a fundamental fact, if any transportation system is worthwhile, it is worth whatever trouble and expense may be necessary to make it safe. There are so many different ways of accomplishing safety that there is absolutely no excuse for failure to make vehicles safe. It is simply a matter of proper design; that is, suitable design, and organizing for the purpose. So, for present purposes, we will assume that safety is a part of the general economics of the subject; in other words, we will take it into account in our cost figures by including the cost of safe design and organization.

The third fundamental question of investors, which we encounter more and more frequently and is the only logical basis for development is, "Will it pay?" I do not refer here to any individual investor. We can take it for granted that any man who puts his money into a business hopes to get some personal profit out of it. I refer here to the broader question of whether an enterprise will pay generally, economically, for society as a whole; after all, that is the only sure foundation upon which we can establish any big industry of this kind. This matter of profit involves some factors that should be of extreme interest to anyone interested in the subject or, indeed, to anyone who is interested in life itself, because transportation is a very intimate factor in modern life.

Fundamental Factors

The fundamental factors are length of haul, mileage cost, cargo or passenger capacity and the amount of business it is possible to obtain in any one class. The length of haul and mileage cost go pretty much together. I am working out the transportation cost per 1000 lb. per 1000 miles for different lengths of haul. The standpoint that I am taking for this is not passengers, fundamentally, but freight. I realize that this is a somewhat novel procedure, but I feel that it is the more fundamental standpoint, and it can be worked out readily later in terms of passengers. The first thing to do is to determine on certain basic costs; that is, to take a certain typical more-or-less familiar case, the costs of which we know, and then consider how the different items can be classified with respect to their source; especially, to determine how they vary for different other conditions, particularly for changes in speed and size.

[1]M.S.A.E.—Consulting engineer, with Alexander Klemin and Associates, New York City.

TABLE 1—BASIS FOR AIRPLANE COSTS,[2] CAPITAL ACCOUNT

Items	Cost
One airplane, including powerplant, at $4 per lb.	$30,000
One-half of oversize hangar space	15,000
Land, one-eighth of 80 acres	30,000
Shops, etc., one-eighth of total cost	20,000
Offices and Miscellaneous, one-sixteenth of total cost	20,000
Working Capital and Reserve	100,000
Total	$215,000

[2]For one 800-hp. all-metal airplane of 15,000-lb. gross lift; maximum speed, 105 m.p.h.; average landing speed, 60 m.p.h. Costs include a proportional share of all equipment, assuming an average of eight planes on the station at a time.

Table 1 shows the capital account for the base airplane-line. This is simply an assumed layout for an airplane line, based on certain arbitrary assumptions. The only claim I make for the figures is that they are generally comparative for the different transportation vehicles. I have taken as authorities the most optimistic of the experts in their particular lines. It should be noted that the costs are not to be taken as proper for figuring actual rates, profits and the like; in that case we must figure high. In this case I am figuring rather low to obtain comparative figures all the way through. On the capital account, for example, I have charged uniformly 8 per cent interest. Table 2 is the yearly operating account for airplanes under certain assumptions. Some engineers may say that it is too good and that this cannot be achieved with the planes we have available at present. I know it cannot be done with made-over war-planes and, if one has other ideas of what can or cannot be done, by all means let him substitute his own figures, if preferred.

Table 3 shows the general method by which the comparisons are worked out. It comprises a series of columns, headed by the quantity which governs the variation of each of the items. Column 2, for example, comprises all costs which depend only upon the carrying capacity of the vehicle. Column 3 depends upon the powerplant, including fuel. Column 4 depends upon the length of route, which is another way of saying that its costs are those due to the landing and starting of the plane. Column 5 comprises certain expenses due to the handling the cargo itself, which are not at all dependent upon the capacity of the plane, but upon the number of pounds handled, whether distributed between one or a dozen planes. After these costs are summed up in Column 6, the coefficient of variation is worked out for each column,

TABLE 2—YEARLY OPERATING COSTS OF AIRPLANES[3]

Items	Per-centage	Cost
Interest on Investment	8	$17,200
Insurance — Airplane	20	6,000
Insurance — Terminal	1	800
Depreciation — Airplane Powerplant Renewals	..	70,000
Depreciation — Remainder of Airplane	20	3,500
Depreciation — Terminal	5	2,500
Maintenance — Airplane Powerplant	..	20,000
Maintenance — Remainder of Airplane	..	10,000
Maintenance — Terminal	..	3,000
Operating personnel — Airplane Powerplant	..	15,000
Operating personnel — Remainder of Airplane	..	10,000
Operating personnel — Terminal	..	10,000
Miscellaneous Overhead	..	35,000
Gasoline and Oil, average 40 cents per gal.		77,000
Total per year		$280,000

$$\frac{280{,}000 \times 1000 \times 1000}{2920\ (103 - 11.5) \times 0.49 \times 15{,}000} = \$143 \text{ per 1000 lb. per 1000 miles.}$$

$$\frac{800 \times 2920 \times 0.75 \times 0.60 \times 0.40}{6} = \$70{,}000 = \text{Theoretical cost of gasoline.}$$

[3]For an 800-hp. airplane on a steady route of 200 miles, flying one-third of the total time; average air-speed, 103 m.p.h. at three-quarter of full power; altitude, 7000 to 9000 ft.; four regular trips per day.

TABLE 3—AIRPLANE UNIT COSTS[4]

Items	Item Varies As: 1 / $C(v-11.5)$	P / $C(v-11.5)$	1 / Cs	1 / s	Total
Col. 1	Col. 2 Per year	Col. 3 Per year	Col. 4 Per year	Col. 5 Per year	Col. 6
Interest	$13,200	$4,000			$17,200
Insurance	4,000	2,800			6,800
Depreciation	4,000	70,000	$2,000		76,000
Maintenance	12,000	20,000	1,000		33,000
Personnel	10,000	15,000	500	$9,500	35,000
Overhead	15,000	5,000	5,000	10,000	35,000
Fuel		71,500	5,500		77,000
Total	$58,200	$188,300	$14,000	$19,500	$280,000
Coefficient	1,330	20.400	700	2.000	
Unit Cost	$30.00	$95.90	$7.10	$10.00	$143.00

[4]Cost, in terms of dollars per 1000 lb. per 1000 miles, equals $(24{,}000 \div [C\ (v - 11.5)])\ (6.5 + P) + 700/Cs + 2000/s$.

and then the unit cost per million pound-miles, and the results are combined finally in the general working formula shown.

Tables 4 and 5 show the same line-up for airships. One interesting fact is brought out in this specimen case; the airship capital account is nearly 10 times as much as the airplane account, but the operating cost is only about double, for a carrying capacity vastly greater. The classification of the costs is worked out in a similar manner as for airplanes, except that another variable, size, has been taken into account also.

Fig. 1 shows the general effect of variation in size for a constant speed of 70 m.p.h. The long and tedious work of calculating the effect of size on the carrying capacity, which of course is vital in connection with the unit cost, is omitted. Fig. 1 shows the great effect of size. The scale of volume is at the bottom. Vertically, we have the percentage of cargo as compared to gross displacement, and also the cost of haulage in terms of dollars per 1000 pounds per 1000 miles. The heavy curves at the top are the carrying capacities for routes of different length, running from zero to 8000 miles. It is evident that the size for the largest percentage of carrying capacity increases very markedly with increase of distance. One would expect this, but I think no one expected such huge sizes. For instance, a route of 4000 miles, which corresponds to many feasible distances across the Atlantic, requires a ship of 3,000,000 cu. ft. of gas capacity to negotiate it at all at a speed of 70 m.p.h. The dirigible R-34 had a speed of slightly over 50 m.p.h. To obtain reasonable economy, judging from the cost curve, we must go up to at least 10,000,000 cu. ft., and for maximum economy to about 50,000,000 cu. ft., which is far larger than anything we have at present. I have not assumed any radically new discoveries in the way of design or other improvements of that kind, other

TABLE 4—BASIS FOR AIRSHIP COSTS,[5] CAPITAL ACCOUNT

Items	Cost
One Rigid Airship of 2,000,000-cu. ft. capacity; maximum speed, 80 m.p.h. — Powerplant, at $5 per lb.	$100,000
One Rigid Airship of 2,000,000-cu. ft. capacity; maximum speed, 80 m.p.h. — Remainder of Airship at $8 per lb.	500,000
One half of oversize hangar space, or one single hangar	600,000
One Mooring Tower and Equipment	50,000
Land at one Terminal, one-half of 160 acres, ½ mile square	200,000
One-half of cost of Gas Plant, Powerhouse and Airships	100,000
Offices and Miscellaneous, one-quarter of total cost	100,000
Working Capital and Reserve	600,000
Total	$2,250,000

[5]For one airship and its own share of equipment, assuming two airships handled per day at each terminal.

than mere size alone. I have worked out the steamship, the railroad and the motor truck on rather a similar basis, using the best authorities obtainable for the effect of length of haul and the mileage cost.

Inherent Value of Speed

We come next to the factor of time-value, or the inherent value of speed. That is already a well recognized factor in American transportation, but it is especially important in aircraft, which claims speed for its great prerogative. In fact, it would not be very far outside the limits of what is justifiable to agree to forget about everything else and to say that if the airship and the airplane cannot succeed on a basis of speed, they cannot succeed at all. The method of measuring the time or speed-value is of course an important matter. I have taken that in the very simplest terms, as represented by the value of any given goods per hour per 1000 lb.; that

TABLE 5—YEARLY OPERATING COSTS OF AIRSHIPS[6]

Items	Percentage	Cost
Interest on Investment,	8	$180,000
Insurance — Airship	10	70,000
Insurance — Terminal	1 to 2	17,000
Depreciation — Airship Powerplant Renewals	..	180,000
Depreciation — Remainder of Airship	30	150,000
Depreciation — Terminal	5	48,000
Maintenance — Airship Powerplant, overhauls, etc.	..	50,000
Maintenance — Remainder of Airship, current repairs	..	30,000
Maintenance — Terminal, current repairs	..	20,000
Operating Personnel — Airship Powerplant	..	40,000
Operating Personnel — Remainder of Airship	..	30,000
Operating Personnel — Terminal	..	120,000
Miscellaneous Overhead	..	150,000
Gasoline and Oil, average, 40 cents per gal.	..	290,000
Hydrogen ($1 50 per M, materials only)	..	25,000
Total per year		$1,400,000

$$\frac{1{,}400{,}000 \times 1000 \times 1000}{4380\ (70 - 10) \times 0.336 \times 150{,}000} = \$106 \text{ per 1000 lb. per 1000 miles}$$

[6]For a 2,000,000-cu. ft., 2480-hp. airship, on a steady route of 1000 miles daily, except when laid up for repairs. The ship is assumed as being laid up one-half the total time and to be running the other half of the time at an average of two-thirds the maximum horsepower, giving an air-speed of 70 m.p.h.

is, if we have 1000 lb. of material of some kind on which it will pay us to save 1 hr. of time, we figure what the saving is and that is the gage of how much we are able to pay for increased speed. So, we will take the time-value of the cargo in terms of dollars per 1000 lb. per hr. For example, suppose some fruit is ordered from California for delivery in New York. If it came by the ordinary slow freight, a large amount would spoil. It costs more by fast freight but the net economy is greater if we save enough of the consignment to make up for it. This is the big factor that must be taken into account in all analyses of air-transportation proposals.

Fig. 2 shows the development of the principle for one particular type of carrier, the airship. This is prepared from about 1000 calculations, covering different conditions of use. The same method can be applied in principle to any form of transportation. The vertical divisions with figures at the bottom represent the length of route between stops. The horizontal divisions with figures at the left represent the time-value of the cargo per 1000 lb. per hr. Taking a route 3000 miles long and a

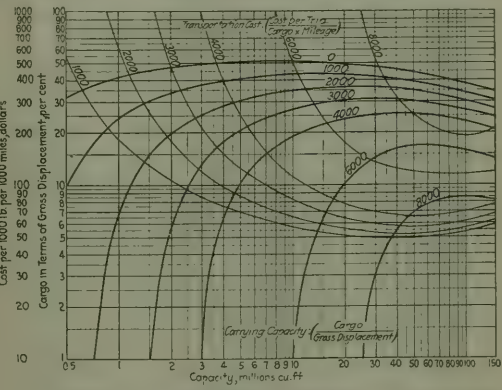

FIG. 1—CAPACITY AND COST CURVES OF COMMERCIAL AIRSHIPS BASED ON AN AVERAGE AIR SPEED OF 70 M. P. H.

cargo with a time-value of $1.70 per 1000 lb.; starting with a value of $1.70 at the left, we run horizontally over until we strike the 3000-mile mark, and spot the intersection; the curved lines running through the same point give the other data that are sought. First of all, take the line which is marked "transportation cost." This shows an actual cost of transportation of $53 per 1000 lb. per 1000 miles. The size of ship for the maximum ultimate economy in this case is 41,000,000 cu. ft. and the speed at which it is most economical to travel is 349 m.p.h. It will, of course, be said that these sizes are out of reach of present construction. They are, to the extent that we have not produced them yet but, as mentioned before, this requires only engineering work and involves no new discoveries.

Fig. 3 is a general combination in a rough way of different transportation systems that will be available after proper organization of the aircraft systems. This is worked out on a somewhat different basis, to simplify it. On such a broad scale we cannot include all the different routes that we did with the airship alone; hence we take for each of the primary systems, the railroad, the steamship and the airship, an assumed route of 1000 miles. For the secondary systems of motor truck and airplane, we take a route of 200 miles each. Along

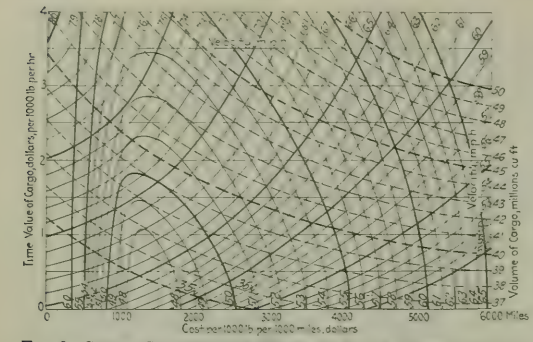

FIG. 2—CURVES SHOWING THE ECONOMIC VALUE, SPEED AND COST FOR CARGO OF VARYING TIME VALUE CARRIED OVER VARYING DISTANCES

the bottom we have the net effective speed in miles per hour. In Fig. 2 it was in terms of the air speed of the airship but, in a combination chart of this kind, that does not mean anything. A fast freight-train on a railroad may go 17 m.p.h. while it is running but it may spend as long a time waiting for other trains to get by. So it has been necessary to work out all the different factors involved and arrive at some kind of estimate of net speed, including the time required to get in and out of terminals, and to load and unload. In explanation of the motor-truck curve I would say that I have not assumed in this case any time or cost charge for loading or unloading. The vertical divisions in Fig. 3 are on a logarithmical scale. This scale runs from a transportation cost of 10 cents to $10 per 1000 lb. per 1000 miles.

The steamship is the only carrier that gets below $1 per 1000 lb. per 1000 miles even under the most favorable conditions possible. Actually, it will cost more than that for usual conditions, including partly filled boats. As I said, Fig. 3 is for ideal conditions all the way through. The railroad comes next in cost and the airship next to it. The airship curve is very nearly horizontal until it finally shoots up when it gets to about 100 m.p.h. It is usually assumed that the airplane exceeds the airship in speed; but it must be noted again that Fig. 3 shows effective speeds and not the actual speeds; we are basing our figures on what we have in actual operation at present. It is a perfectly logical development from present knowledge and material.

The distinctive fields for these different transportation systems are shown in Fig. 3 in the form of shaded areas. The line of figures below the speed figures gives the

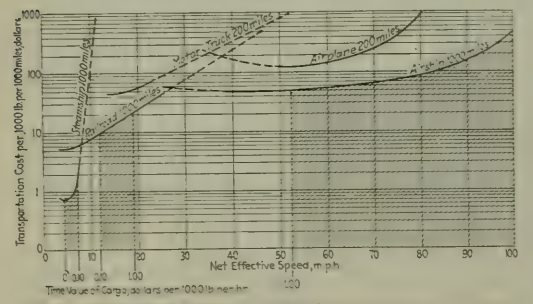
Transportation Cost per 1000 lb. per 1000 miles, dollars
Net Effective Speed, m.p.h.
Time Value of Cargo, dollars per 1000 lb. per hr.
Steamship 2000 miles
Motor Truck 200 miles
Airplane 200 miles
Airship 2000 miles
Railroad 1000 miles

FIG. 3—COMPARATIVE COST OF FREIGHT TRANSPORTATION BY STEAMSHIP, RAILROAD, MOTOR TRUCK, AIRPLANE AND AIRSHIP

time-value of the cargo in dollars per 1000 lb. per hr. The economic range for steamships is from zero to 10 cents per 1000 lb. per hr., which is represented by the shaded area running from 4 to 7 m.p.h. The railroad starts where the steamship leaves off, which makes it appear paradoxical to have a gap in the speed-range. However, reflection will show why it occurs. The economic railroad-range starts at 10 cents and runs up to $1 per 1000 lb. per 1000 miles. I am assuming that one might ship by either water or rail. Again, beyond the railroad speeds we get a big gap up to where the airship begins to be effective. It is not a gap in an economic sense but from the practical standpoint of speed. The airship does not begin to be able to compete with the railroad, with an effective speed of 19 m.p.h., until it reaches about 52 m.p.h., which includes landing and all else; economically it starts where the railroad leaves off, at $1 per 1000 lb. per hr. The motor truck and the airplane cannot be worked into this particular scheme because the latter's chief value depends upon the special uses to which it can be put. This is inclusive of non-schedule work, for instance, and all work of limited capacity, where the carrying of limited loads is required and it is necessary to make exceptional speed over short distances with small loads; finally, in the case of the motor truck it includes the supreme advantage of being able to deliver to destination.

TIME-VALUE CARGO CLASSIFICATION

I will outline briefly in practical terms what it means to classify cargoes according to time-value. For the steamship, which worked out from zero to 10 cents per 1000 lb. per hr., this includes all bulk cargo up to a capital value of $10 per lb., which comprises everything in the nature of coal, ore, stone, wood, castings or anything of similar nature that is not affected by time, other than a moderate interest charge on the investment. For railroads the economic range is up to $1 per 1000 lb. per hr. This includes all non-perishable bulk cargo up to $100 per lb. capital value; the airship starts from there and goes on up. So, it is evident that until we reach such things as jewelry, gold and silver, the capital value does not have much influence; but items that have perishability, such as news value, or human value, including passengers, mail and anything of that type in which time itself is of importance, do make a huge difference. I cannot enumerate all of the different articles which belong in this classification. Among other things the aircraft class includes all mail and practically all passengers, for long routes. The passenger problem is a study in itself.

One thing that must be kept in mind in all these comparisons is the difference between day and night. I have worked the points out on a uniform basis to be consistent, but most commodities and practically all passengers will pay more for the saving of time in daytime than at night, so that any carrier which is limited to daytime travel is under a very great disadvantage. I hope that the airplane will be worked up to overcome that disadvantage soon. For the airship, we can say now that it is easier and safer to handle at night than in the daytime.

As to the future, I have used the word "immediate" in the title of this paper from the standpoint of present knowledge and the materials available rather than from that of time itself. We are on the threshold of aerial navigation. We have airships in sizes up to 2,000,000 cu. ft. that could be run at a very fair profit with goods

of a time-value of $4 per 1000 lb. per hr., or with passengers whose time is worth $8000 per year or more. This is for airships which are in operation at present. The transportation cost can be cut down more than 75 per cent merely by standardization of methods, organization for the purpose, designs which are suitable and, particularly, enlargements in the size of airship units. In this respect I believe that construction and operation must go together at the start. The more closely we can put them together, the better it will be. Furthermore, airships and airplanes should be operated simultaneously and in close cooperation, because they reinforce and supplement each other in almost every possible way. The general tendency at present is to get away from thinking in terms of any particular types. We are coming to the time when, with the growing recognition of the importance of air-travel development, we will not talk so much about designing the Zeppelin type of airship, the all-metal airplane or any other particular type. Instead, we shall go after the suitable type as an engineering problem and work it out to best suit the conditions. When we shall have done that, we will find that nothing we have done in the way of calculating the amount of available business will approach the actual possibilities. When telegraph lines were first being put in 100 years ago and even more recently than that, particularly the cable laid across the Atlantic, the question of what business the lines would attract might have been asked. Then we were in the position of having to charge rates for the transmission of messages over 100 times as much as those for transporting letters over corresponding distances. It might have been argued that no message could be so important as to justify such a large increase in cost. It is impossible to analyze a new business completely. The interesting fact is that the establishment of the telegraph lines and cables created their own business in large measure. In the case of the airship, when we are so organized that we have a network of airship transportation all over this country, it will be feasible to segregate and specialize our different manufacturing industries much more closely than we do at present. We could produce all our milk on one central farm and ship it to every point in the United States for a few cents per quart. I do not say that this will be done but such a thing is possible.

APPENDIX

The assumptions used as a basis for the calculations are as follows:

(1) All carriers are considered as being fully loaded
(2) The most economic size and number of units are considered, according to Tables 1 to 5
(3) The present methods of design, construction and operation are considered, with an allowance made only for change in size and standardization
(4) Invested capital is charged at 8 per cent per year

Fuel cost is taken as follows:

(1) For the steamship, fuel oil at $18 or coal at $7.70 per ton of 2240 lb.
(2) For the railroad, coal at $6 per ton of 2000 lb.
(3) For the motor car, gasoline at 30 cents per United States gal.
(4) For the airplane and the airship, gasoline at 35 cents per United States gal.

Inclusive of construction cost, materials are assumed to cost as follows:

(1) For the steamship, 23 cents per lb. for the powerplant and 12½ cents per lb. for the remainder, which is mainly of steel
(2) For the railroad, locomotives at 18 cents per lb. and 8 cents per lb. for the remainder, which is mainly of steel
(3) For the motor car including the powerplant, 80 cents per lb., mainly of steel
(4) For the airplane including the powerplant, $4 per lb., utilizing steel and duralumin
(5) For the airship, $5 per lb. for the powerplant, mainly of steel; and $8 per lb. for the remainder, utilizing duralumin and fabric

The cost per mile is estimated on a basis of great-circle distance. For the steamship, railroad and motor car the average actual routes assumed are 33 per cent greater than the great-circle route; for the airplane and airship, the route is the same as the great circle.

An allowance of 6 per cent is made for heavy seas in the case of the steamship; about 40 per cent for switching and the like, slightly varying with speed, for the railroad; and about 10 per cent for bad roads, towns and the like for the motor car, varying slightly with the speed. For the airplane, the average cruising speed is taken at three-quarters of full power, further reduced by 11½ m.p.h. to allow for average winds. The average cruising speed of the airship is taken at two-thirds of full power, further reduced by 10 m.p.h. to allow for average winds.

The terminal time in and out, including the handling of the cargo, is from 4 to 8 days for the steamship, depending upon its size; 1 to 2 days for the railroad, depending upon the speed; none for the motor car; 1 hr. for the airplane; and 2 hr. for the airship. No allowance is made for delivery, which is too variable to consider.

The proportion of running time per year is about 55 per cent for the steamship, varying slightly with speed and size; 12 per cent for the railroad and 50 per cent for the motor car, varying slightly with the speed; 33 per cent for the airplane; and 50 per cent for the airship.

Discussion of Papers at the Chicago Truck and Tractor Meeting

THE discussion of the papers presented at the recent Truck and Tractor Meeting of the Society included written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received in time for publication, are included in the discussions. A brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, for the convenience of members who desire to refer to the complete text as originally printed and the illustrations which appeared in connection therewith.

TRACTOR SERVICE REQUIREMENTS

BY J. C. THORPE

THE paper treats of the service, commercial and technical aspects of the subject in turn. The author calls attention to the fact that there can be no such thing as free service, because the customer pays in the end, and gives a specific definition of service. He argues that the engineering departments should urge upon merchandising departments intelligent distribution through dealers, the stocking of an adequate supply of parts and the maintaining of a well qualified mechanical force for the purpose of making engineering development work in the form of farm power automotive apparatus effective.

There is a great need for a suitable system of training mechanics for tractor service work, and there should be a definite plan to assure that men making repairs and adjustments in the field are well qualified.

In conclusion, the author pleads for continued consideration of the subject of accessibility of parts in tractor design, the use of better materials, reduction of weight and the furtherance of a program to increase the number of tools driven by tractors in farm work. [Printed in this issue of THE JOURNAL]

NEED FOR GREATER SERVICE ACCESSIBILITY IN CAR DESIGN

BY T. F. CULLEN

OF the various items of expense in connection with maintaining a car, depreciation probably is the largest single one and insurance, garage expense, repairs, adjustments, tires, gasoline and oil follow in about the order given. Improved service accessibility tends to reduce repair and adjustment costs by decreasing the amount of repair labor necessary and to retard depreciation by enabling the owner to maintain his car in good running order at a minimum expense. Moreover the fact that a car is unusually accessible for all classes of repair work will enhance its resale value. After elaborating these statements, the author reviews the present status of car design for service accessibility and presents a table showing the comparative service accessibility of 40 representative cars on 25 typical service operations, afterward stating the possible improvements suggested by this survey and illustrating them by diagrams. He then discusses the possibilities for improvement in current models of cars. [Printed in the March, 1921, issue of THE JOURNAL]

THE DISCUSSION

PRES. DAVID BEECROFT:—When Mr. Thorpe spoke of the trinity of cooperation in service, he linked together the manufacturer, the dealer and the owner, and again brought out the thought that too often the engineer is confined to the laboratory and fails to follow his product. In these days when resistance arises, sales resistance in particular, the influence of it comes against the sales end, then against production and lastly against the engineering end, but the engineer can play a much broader part than he has in anticipating these conditions. I hold that only part of the time of the engineer should be spent in the laboratory, and that he should be one of the outside investigators or have in his department or organization men to carry on outside investigations. Why should all outside investigation be left to the sales department when the engineer should be better qualified to interpret and translate into manufacturing and engineering requirements the environment that the apparatus must operate in? I sincerely hope that the engineer will branch out and that his department will comprehend not only a sphere of influence but a sphere of investigation. I believe that the peaks of the curve of sales, where sales resistance seems almost too great, can be largely flattened out. Perhaps there will be none if the engineer investigates the requirements and better adapts the design of his apparatus to those requirements.

Regarding the service end of which Mr. Cullen spoke, I spent a week in going through the State of Wisconsin, devoting my entire time to service organizations. I am pleased with the great progress that is being made throughout the country on what is known as the fixed-price system in charging for service. No matter what the apparatus is, the repair stations sell service. If a motor car is driven to a service depot, before it gets inside a representative hears the complaint of the owner,

makes a complete examination, fills out a chart and enters on that chart definite charges for all needed work. He has a complete record made up in which an accurate average time for each particular job has been arrived at, in his own and in other shops. This service work will come back to the engineering department in this way. In one place the charge is $12 for grinding valves and removing carbon, while just across the street the charge is $16 for the same job on an engine with the same number of cylinders. The public will demand an explanation of the difference in price. This fixed-price system is inducing the public to think of service and of accessibility in terms of dollars and cents.

Some time ago I had a repair bill for $121 on which 96 hr. in labor was charged on one line without any other explanation. That labor was at a little over $1 per hr. That kind of a bill never drives home the story of the relationship between service and dollars, but with the fixed-price system in which the owner gets his bill with the amount in the column at the right for each operation, he sees every item, is set thinking and translates the accessibility of his car into dollars and cents as he never translated it before. This movement is gaining great headway. Two distributors of one of our largest manufacturers have worked the system out and had it in operation for 1½ months, and 16 other distributors located throughout the country have sent their service men to the distributors to study the problem. Within a few months they will have the system in operation. They find that there is a greatly improved relationship between the owner and the dealer when the owner is informed in advance what repair work will cost him. One of two dealers who sell rival cars on opposite sides of the same street told me that when he took in exchange for a new one a car sold by his rival across the street, he never thought of sending that car over to the man who sold it to have it repaired because he felt he would be imposed upon. On the basis of the fixed-price repair system he would take in the car sold by his rival and not attempt to overhaul it but have it overhauled by the man who sold it.

Bringing this back to the engineer, the public is being educated on what service means in dollars and cents; I think it is very important at this time that we take due recognition of that. I feel that the engineer must get out beyond his laboratory. The laboratory is unquestionably his field, but he must go beyond that. We might explain that by using as a parallel the fact that we are all very much puzzled as to the commercial application of aviation, and as to who will work it out. Who is to carry on the investigation? There is nothing to sell, there is no salesman and the buyer does not know what to buy. It is the engineer's duty to go out and study the conditions and then to meet them by efficient and economical design. If that be true, it is equally true in the fields of the passenger car, the tractor and the motor truck.

DENT PARRETT:—We who have had experience in the tractor business have encountered many problems in designing the machine so that it can be taken care of easily. A motor truck or an automobile experiences some trouble, but such a vehicle can be towed into a service station very readily. With the tractor, very often the work has to be done in the middle of a large field with no facilities at hand. For that reason, it is even more important that the various parts which require attention on a tractor can be reached without removing a number of other parts. In the later tractor designs this has been taken into consideration and real progress has been made in this respect. There are many opportunities for further improvement, so that any part can be removed in the field without the use of special facilities.

H. L. HORNING:—It is our custom to make our service men acquainted with laboratory methods and our laboratory men are sent out on the road to settle the difficulties which are met by the men who are using our product. It is our practice to make both the research and service men exchange positions. We find that this gives the most satisfactory result in the end. We feel that a research and laboratory man should be able to see the results of his work in the field just as the artillerymen need someone to tell them where their shots are hitting. We have been able through laboratory methods to improve the field performance to a point we never reached without laboratory methods. We find that our book on Care and Operation is the most eagerly sought printed matter we turn out. It is being used by a great many who are not using our engine. People are anxious to obtain knowledge, but are limited in their resources.

L. M. STELLMAN:—We are interested in bringing the subject of service accessibility to the attention of the entire profession. We were interested in the chart in Mr. Cullen's paper which shows the comparative service accessibility of 40 representative automobiles on 25 typical service operations. On account of some omissions this chart does not seem fair because, where an item is considered perfect, 4 points are allowed in connection with the score of that particular item. Further, where an item is left out because no trouble was encountered, no points are allowed for that item. Taking the case of car No. 18, for instance, for 5 items the count is left out which permits 20 points to be left out or allows 80 for a perfect score. Instead of having a perfect score, this particular car has 76 on an average of all operations, 19 points being left out in connection with its score. Figuring 19 points out of 80, Mr. Cullen derives approximately 76 per cent. If the 19 points were figured on the basis of 100 the average of all car operations would be approximately 82 per cent.

We have considered some additional points and offer them for discussion.

(1) Designs should provide for accessibility in lubricating, and lubrication should be required less frequently on parts such as spring pivot bolts, driveshaft and steering connections. Further, the parts to be lubricated should be divided into three classes: (*a*) engine, (*b*) fast-moving or heavy-duty parts and (*c*) minor parts such as brake-rods

(2) All nuts and bolt-heads should be of hexagonal form and have sufficient clearance around the head so that commercial socket-wrenches can be used

(3) Cap-screws should be made sufficiently strong to withstand the abuse of quick removal and reinstallation without undue care

(4) Where gaskets are used to prevent oil leakage, the cap-screws should be sufficiently close together so that an average mechanic can get a tight joint and freedom from bulging due to any excessive tightening of cap-screws

(5) Felt washers on front and rear wheels should be replaceable readily without too much care being required

(6) Wear should be localized in small and relatively inexpensive and readily replaceable parts. It is often better to have a part wear more rapidly and be easily and quickly replaceable with a small amount of labor, than to have a longer-wearing part that involves expensive replacement

(7) The expensive material and labor should be used for

the parts that are most enduring, bushings or simple parts which can be made cheaply, being inserted to take the wear, as in the case of drive line universal joints

(8) Wiring should be arranged so that it can be checked up readily, no connections being in inaccessible places. It is better to have all wiring run to a central switchboard

(9) The squeaks and rattles in the body and in the sheet metal work, such as the guards, should be eliminated, as well as the rattling of doors and windows of closed cars

(10) Easy adjustment of transmission and rear-axle bearings should be provided. The bearing installation parts should be made simpler, more easy to handle quickly and so that they can be reassembled readily at a repair-shop without consequent oil-leakage

ENGINEERING ANALYSIS APPLIED TO TRUCK SELLING

BY N. J. OCKSREIDER

IN this day of transportation engineering, the requirements of each customer must be diagnosed accurately and the economic waste due to wrong selling eliminated. Stating that 32 classes of trades, divided into 350 subclasses, use motor trucks, the author expressed the view that, in applying the science of selling by analysis, it is necessary to know the cost of shipping every pound of goods, deducing in turn the correct size of truck for a given kind of work.

Referring to the fact that a truck cannot be designed to stand up under all conditions and that selling a truck which is unsuitable for a particular task means a dissatisfied customer, the author gives the opinion that a truck of mediocre merit will in many cases perform more satisfactorily than the best truck built operating under improper conditions.

The author makes a broad-minded and valuable contribution in his statement of the factors to be observed in determining the proper type and size of truck to meet a given customer's requirements in the most satisfactory manner, pointing out the many advantages derived from the making of unbiased recommendations and taking all steps possible to prevent overloading.

THE DISCUSSION

CHAIRMAN B. B. BACHMAN:—I think Mr. Ocksreider summed up the situation rather tersely in recognizing that some of the competitors of his company are operating under the same general plan, possibly calling it by a different name. I am reminded in that respect of the similarity of what we have been pleased to call "efficiency engineering" in production lines. To draw a parallel, there is no question that in production lines the application of so-called efficiency methods has been of inestimable benefit, and that without the application of them our present system of production would be impossible. However, with the successes that have been accomplished and the presentation of principles which is possible only in the abstract, there have been those who considered themselves competent to take partial expression of principle and apply it in hidebound form. The results have been unfortunate. Selling is undoubtedly a science, just as is the design of an article or the production of it. As science has been slighted in engineering and in production, so it has been slighted in selling, but probably to an even greater extent. Mr. Ocksreider said that success in the application of correct methods depends upon the application of commonsense principles. It seems to me that in business engineering, production or selling, it all comes down to a basis of commonsense. Unfortunately, that is not such a common possession as its name indicates.

P. M. HOLDSWORTH:—In making analyses such as Mr. Ocksreider describes there must be some cases in which a Packard truck is not found to be the very best truck for the work. What would be the recommendation of the man that made the anlaysis in such a case?

N. J. OCKSREIDER:—We advise the customer frankly if a Packard truck is not fitted for his needs; or if horses are the better equipment. To give a concrete example, we had a case recently in which we analyzed the prospective buyer's needs. He thought that he could improve his hauling problem with the aid of a truck. Our salesman thought so at the time. After the analysis was completed we found that a truck, particularly of the size which we build, did not fit his needs. He had to do one of two things, retain his horse equipment or buy a ¾-ton vehicle. We reported accordingly and did not sell him a Packard truck.

MR. HOLDSWORTH: — Under certain circumstances, would you recommend an electric truck?

MR. OCKSREIDER:—Yes, we have done that. A particular instance is in the case of the Curtis Publishing Co., of Philadelphia. We analyzed its problem some time ago, recommended electric vehicles and it is now operating them.

S. E. BATES:—In the analyses are the different kinds of trailers taken into account and recommendations made accordingly?

MR. OCKSREIDER:—Yes.

MR. BATES:—There are probably 10 to 20 more kinds of trailers offered than of trucks.

MR. OCKSREIDER:—We take the requirements of the problem and prescribe absolutely the thing that we think will solve it with as nearly 100-per cent efficiency as possible. We have to recommend trailers in a large number of cases.

F. J. SULLIVAN:—What does the Packard company do when it makes a recommendation to a purchaser of trucks and after the trucks have been purchased the owner does not adhere to the recommendation, but overloads them for example?

MR. OCKSREIDER:—We protest sometimes; we try to follow the matter through, although it is difficult to keep a customer from overloading. When we make a survey we point out the consequences that can be expected and the inefficiency caused by overloading. We take into consideration deliveries and point out to the purchaser that he will hurt his own efficiency. If he persists, we are absolutely helpless. We often go to the drivers when they are out on the street with an overload and caution them.

J. G. CARROLL:—The work of the large electrical manufacturing companies in the transportation field is really pioneer work. For example, the installation of a mine-

haulage system involves a thorough study of the customers' underground conditions. The companies do not recommend any equipment that would in any way increase haulage costs for the customer. If their own equipment does not fit, they tell the prospective customer so and recommend the size of the equipment he needs, the number of units and the method of installing the entire system. They give him also relative operating costs as closely as they can. This sort of procedure results in a transportation system that is as highly efficient as it is possible to make it. In the past some of the electric-truck companies have failed due to their not having analyzed the conditions under which the trucks had to operate. There were many complaints which gradually worked against the companies, until today very few of the original electric-truck firms are in existence. I have been connected with the application of motors in the electric-truck industry since it first started. I have seen companies grow up and drop away. Customers appreciate the advantage of being able to secure expert assistance from manufacturers in the solution of their transportation problems.

THE APPLICATION OF STEAM POWER TO AN AUTOMOTIVE TRUCK*

BY L. L. SCOTT

THE paper describes the steam-operated 2-ton truck developed by E. C. Newcomb and the author. It has a direct drive-shaft from the engine to a rear axle worm, with a 5 to 1 gear-reduction at the axle, and is operated without any transmission or clutch. The engine has been simplified since the author's first report on it in 1919, the changes relating to valve-gear, crankshaft and cam design. After presenting illustrations and describing them, the author gives nine specific advantageous features in this steam powerplant and comments upon them, submitting charts of torque curves which are analyzed. The engine control, fuel, oil and water consumption are next described and discussed and the results of acceleration tests are then shown in tabular form, with comments thereon. [Printed in the February, 1921, issue of THE JOURNAL]

THE DISCUSSION

A. L. NELSON:—With reference to Mr. Scott's discussion of the steam engine there is one point in comparing it with the internal-combustion engine which I think we should not fail to consider. Apparently he assumes that the inefficiency of the gasoline engine at partial loads will continue to remain as great as it has been. We should not assume that the internal-combustion engine will not be developed further. I believe that there is a very good chance of increasing the efficiency of the internal-combustion engine, not at full loads particularly but at the loads under which the engine is used in a truck. I think it would be well worthwhile to make comparisons with this in view.

WILLARD J. GRAMM:—How does Mr. Scott take care of the problem of freezing in winter?

L. L. SCOTT:—It is taken care of in one way by putting alcohol in the water. The water mileage in cold weather is such that this can be done without excessive cost. If the truck is being operated every day, it is not necessary to do anything for the reason that all parts containing water are under the hood. Freezing will not take place because in our particular arrangement there is about 4 in. of refractory material at the bottom of the boiler that retains heat for from 14 to 16 hr. In the event of freezing, the boiler, for example, will not be damaged in any way. The tubes will withstand a pressure of about 30,000 lb. per sq. in. and ice at that pressure is impossible. We are using alcohol right along in our touring car and our truck in cold weather.

Mr. Nelson spoke about the future. There are possibilities of all sorts of things. We have been working with the internal-combustion engine for many years and are making comparisons with what we have today. I mentioned also the possibility of future developmet of a steam plant that can show much greater efficiency than has been shown with steam plants to date. Taking the two types of apparatus as they are today, we are able to show a higher fuel mileage on a lower grade of fuel. Of course, there are many other things to take into consideration besides that one point, such as the ability to burn the fuel regardless of its cost, the cost of oil, repair bills and the like.

C. O. GUERNSEY:—I think that none of us should close our minds to any possible line of development that would permit us to use a greater percentage of the crude oil. I do not entirely agree with what Mr. Scott states. I have just made some rough calculations taken from figures given in Mr. Scott's tables. I may have made some assumptions that are not warranted but the figures I have are I think approximately correct. In one of the runs he reported 7 miles per gal. of oil with a total weight of, roughly, 5½ tons. I have assumed the road tractive effort required to be 60 lb. per ton, this being probably the requirement for an average country road, which I understand was the condition under which the truck was operated. Assuming 19,000 B.t.u. per lb. of oil burned, he is operating with an overall efficiency of somewhere around 11 per cent. That is neither particularly worse nor much better than we can get ordinarily from a gasoline engine.

Mr. Scott quotes some mileage figures for various trucks. I have no doubt that they are reasonably close to what is obtained in ordinary use in the hands of the average user, the trucks probably not being in the best of condition. However, Mr. Scott's figures are taken for experimental runs. I think for comparison we should give the gasoline engine the benefit of the same condition. It is easily possible with a conventional 2-ton truck without any special tuning up or anything of that sort to get from 7 to 9 miles per gal.

Undoubtedly, the steam engine does hold some possibilities. If Mr. Scott can develop a powerplant having an overall efficiency of some 28 per cent, as he mentions, we certainly should be very much interested. It seems to me that there is another line of development which possibly is being looked into under cover, but which has not been discussed to any great extent at the Society

meetings; that is, the constant-pressure type of engine, possibly a combination of the steam and the internal-combustion engine systems. A theoretical diagram of such an engine shows a thermal efficiency of from 41 to 48 per cent, depending upon the compression used and other conditions. Such a system would have also the advantage of operating at a better efficiency under part than under full-load conditions. This is another avenue that we should not overlook.

R. B. HALL:—Has Mr. Scott used double or triple-expansion engines in his steam truck or experimented with them?

MR. SCOTT:—We have not. The only type of engine we have ever used is a simple uniflow or semi-uniflow double-acting engine. We have got steam rates below 12 lb. per hp-hr. This equals any test result that I know of with engines anywhere near the size of ours, including triple-expansion engines. We did not feel justified in using anything more complicated than the engine we have.

THE CARE AND MAINTENANCE OF MOTOR TRUCKS

BY N. J. SMITH

THE object of this paper is to point out some of the difficulties of motor-truck maintenance and to suggest lines of improvement. The buyer and user of a motor truck sometimes experiences disappointments due to the lack of coordination between the engineering and sales departments of a truck company. The term "service" is often misunderstood by the purchaser and misrepresented by the salesman, which results in dissatisfied customers. Salesmen should have accurate information on the service policy of their company and on all guarantees which they are authorized to make.

After rehearsing many of the difficulties encountered in truck maintenance, the author discusses in some detail the needed improvements in truck design, passing then to details of maintenance practice and methods of handling repairs. The results stated are those of actual experience, which prove that it is more economical to expend money for the prevention of trouble than to apply the same amount and more toward repairing defects. [Printed in the April, 1921, issue of THE JOURNAL]

THE DISCUSSION

GEORGE T. BRIGGS:—I ask the following questions:

(1) How much mileage do you obtain from a set of final-drive chains, and what is the total maintenance cost during the period of that mileage?
(2) How often do you find it necessary to regrind cylinders and fit over-sized pistons?
(3) How often do you take up connecting-rod big-end bearings?
(4) How often do you regrind crankshafts?
(5) How often do you replace the friction disc of the clutch?

N. J. SMITH:—We get about 10,000 miles from a set of chains, depending upon the nature of the work; in hauling coal alone, we have run as high as 15,000 miles; if we are hauling stone or sand, the chains will not last as long.

The care that is given the engine determines the frequency of regrinding cylinders. We have engines in operation which have run over 30,000 miles without the cylinders being reground. Other cylinders have been reground after 15,000 miles. With good lubrication the engines will run years without regrinding the cylinders; lubrication is the big item.

The taking-up of connecting-rod bearings is another thing that is governed to a great extent by the care given the engine, although there are many things that have an influence on that. I would only be guessing at an average, as I did not come prepared with those figures. We have often run engines for 2 years without taking up the connecting-rod bearings; some have run longer than that.

I cannot say when it is necessary to regrind crankshafts. We have trucks more than 4 years old on which the crankshafts have not been reground. We found less than 0.002-in. wear on those shafts. That probably seems like an extreme statement. Lubrication is a main item there, also.

As to how often we find it necessary to replace the friction disc of the clutch, I have had trucks on which the clutch has burnt out within a month's time; other clutches have run years without repair. Unless a driver has an accident or gets stuck and burns a clutch up, we can say that it will last 1½ to 2 years; sometimes longer than that.

A. L. NELSON:—What kind of records are kept on fuel oil economy?

MR. SMITH:—We have a man who studies the amount of fuel and oil used. He spends all his time following the trucks on the street and in the garages. We are paying more attention to this subject than ever before. We are improving our fuel consumption.

F. J. SULLIVAN:—How many miles does one of these trucks make in a month?

MR. SMITH:—We estimate 1000 miles per month.

W. S. NATHAN:—Has Mr. Smith installed any apparatus to reclaim the crankcase oil? What does he do with the oil if he does not reclaim it?

MR. SMITH:—We have a filter in our main garage that we put the oil through. We take out all the dirt and grit and use the oil in our hoists. I have tried reclaimed oil in the crankcase recently, but only experimentally.

W. J. GRAMM:—I believe Mr. Smith mentioned that he included a 33⅓-per cent overload. Is it customary for the company to include that percentage of overload?

MR. SMITH:—Yes.

MR. GRAMM:—Is it possible to do that and maintain the trucks properly without serious trouble?

MR. SMITH:—I can give no statistics for or against it. We are doing it and believe we are successful. We cannot see wherein a truck is not keeping up to its standard as well with a 33⅓-per cent overload. We are watching the speed. We know that speed is more dangerous to the truck than overload. Speed is one thing that we keep away from.

H. M. RUGG:—How large a force of mechanics does Mr. Smith keep at work in the repair-shop? What methods are used to train or instruct them in the work?

MR. SMITH:—Our mechanical force is small and consists usually of men we take on and instruct. We teach them the business.

APRIL COUNCIL MEETING

THE meeting of the Council held in Detroit on April 25 was attended by President Beecroft, Past-President Vincent, First Vice-President Horning, Vice-Presidents Bachman, Crane and Johnston, Councilor Brush and Dr. H. C. Dickinson and O. C. Berry of the Research Committee.

Research Matters

The Research Committee had held a session just before the Council meeting and discussed thoroughly the matter of procedure of the Research Department of the Society authorized to be established at the meeting of the Council held on Feb. 3. It was understood that the work of the department, to be managed by a man of suitable engineering and scientific attainments, would include the correlation of present data from all available sources. Emphasis was placed on the advisability and great value of eliminating duplication of thought and expense in research by joint procedure through the Society, its resourcefulness bringing about the cooperation of many institutions and companies and the securing of desired results relatively quickly and accurately. It is understood that it would be impossible to replace with a central organization general research but it is felt that unnecessary duplication of effort can be gradually eliminated. A number of men starting from different points are much more likely to reach the goal sought. Some results of research conducted 20 years ago are not widely known and should be disseminated for general educational purposes. Work that has been done should not be done over again. It is the view of the Research Committee and the Council that united effort should be exerted on problems that baffle the ability of individuals proceeding separately. The main argument for united effort is that some important problems are not being solved; advance has been made in the vaporizing of fuels currently available but it is not clear that it has been conquered. More fundamental study should be conducted for the benefit of all. The work of individuals as such should not, of course, be interfered with, but joint work on the problems common to all will give the best results to the industry. The individual viewpoint is frequently too narrow. Bases for testing should be stipulated so that comparable results will be possible. That alone would compensate for the coordinative work contemplated.

It is not the intention that the Society shall itself conduct a laboratory but that it shall keep in touch with individual activities and collate and publish test results. Various developments in the industry must be guided along sanely determined lines. It is stated plausibly that in many instances money is wasted in improperly conducted tests and research work. Moreover, with the great duplication of work now prevalent, there is frequently not time available to solve completely any one problem, and there are many problems that are of general interest.

Clear distinction must be borne in mind between development work and research work. The work of the Society as such must stop with the discovery of facts and not extend to the application of them in design or reduction to patented form. The term "research" is used with lack of general understanding as to what research is. One suggested definition is that research is analyzing a problem and securing fundamental data to solve it. Routine tests are not research. Confusion results as to what research is, because research and experimental development go hand in hand.

The Research Department of the Society will confine itself to the collection and dissemination of fundamental information. Duplication of effort is necessary in the application of principles. There should be also intelligent duplication of research work. The human equation holds in research through the effect of unsuspected variables. The human mind is not big enough to assure that a set of test conditions determined by one man is adequate; something overlooked may amount to a fatal defect. On the other hand, mutual knowledge of the efforts of various people may stimulate better work by all of them.

The Society's Research Department will check the test results of different laboratories. The work of the department will be under the supervision of the Research Committee. No engineer will be criticized adversely for not giving information he considers it would be improper for him to give. The information disseminated by the Society will relate to methods only and not bear on commercial phases, such as "makes." The main purpose in mind is to meet the general need for assistance of a fundamental nature. To this end the facilities of many institutions are available.

It is expected that the Research Department will be in active operation within a few months. Its establishment constitutes a step of the first order of importance in the history of the Society and the plans for its work are accordingly being considered with great care.

Finance

The balance sheet as of March 31, 1921, showed that the net unexpended income for the first 6 months of the current fiscal year was $4,462.99. The income for the period was $125,686.55. A statement was submitted of income and expense for the first 6 months of this fiscal year, beginning Oct. 1, 1920, in comparison with the corresponding 6 months of the last fiscal year. This showed that the income for the first half of this fiscal year was $409.08 more and the expense $1,589.13 less than for the first half of the last fiscal year.

The market value on March 31 of the $105,000 par value of Government and railroad bonds owned by the Society was $97,521.50, as compared with $98,268.10 on Feb. 28. The total assets of the Society on March 31, 1921, were $210,773.95, with accounts payable of $11,056.37; the total assets comprise the general reserve of $130,028.52, the unexpended income accumulated during the last 10 years, and special reserves for distribution to income and expense items over the present fiscal year of $69,689.06.

Membership

Seventy-one applications for individual membership and 6 for student enrollment were approved.

The following were transferred from Associate to Member grade: George A. Gastineau and Dean E. Baskerville.

Eighty-two applications for membership were received during March, as compared with 86 for the same month of 1920. Two hundred and eighteen applications were received during January, February and March of this year, as compared with 241 during the same three months of 1920. On March 31 there were 5416 names on the rolls of the Society, including Affiliate Member Representatives and Enrolled Students, as compared with 4701 on the same day of 1920.

Standards Committee

The following additional appointments to the Standards Committee were made, with assignments as indicated:

F. C. Barton—Isolated Electric Lighting Plant Division
H. E. Brunner—Ball and Roller Bearings Division
L. F. Burger—Isolated Electric Lighting Plant Division
A. G. Carman—Non-Ferrous Metals Division
D. L. Colwell—Non-Ferrous Metals Division
V. A. Crosby—Iron and Steel Division
S. F. Evelyn—Electrical Equipment Division and Engine Division
A. W. Kinman—Non-Ferrous Metals Division
C. D. Ryder—Lighting Division
L. D. Simpkins—Non-Ferrous Metals Division
F. W. Slack—Parts and Fittings Division
G. W. Smith—Radiator Division
James A. White—Radiator Division

An Axle and Wheel Division of the Standards Committee was established with the personnel specified on page 606 of this issue of THE JOURNAL.

The most important work of this Division will relate to

consideration of standardization of wheel-hubs for passenger cars and motor trucks, a recommendation for Recommended Practice for front-wheel hubs for motor trucks having been submitted by the Truck Division at the meeting of the Standards Committee held on May 24. The jurisdiction of the Axle and Wheel Division will include also matters of standardization involved in axle and wheel elements, excepting tires and rims.

The following subjects were assigned to Divisions:

PARTS AND FITTINGS DIVISION

Shims
Water-Pipe Flanges

PASSENGER CAR BODY DIVISION

Beads for Wiring
Door Fit Clearances
Door-Handle Escutcheon-Plates
Door-Hinges
Drill Sizes for Wood Screws
Fender-Irons
Leather
Nickel-Plating
Plate Glass
Rolled Sections
Tee Moldings
Top Irons
Types of Bodies
Window Runways

SCREW-THREAD DIVISION

Rivets

STATIONARY ENGINE DIVISION

Babbitts
Connecting-Rods
Crankshafts
Governor Springs
Lubricators and Oil-Cups
Piston-Pins and Bushings
Piston-Rings
Spark-Plug Hoods
Water-Pot (Hopper) Capacity

TRACTOR DIVISON

Non-Freezing Solutions

TRANSMISSION DIVISION

Clutch-Bearing Oiling Mechanism

A. W. Copland was appointed to represent the Society on the American Engineering Standards Committee's Sectional Committee on Gears.

George A. Green was designated as the representative of the Society on the Advisory Board to the United States Government Interdepartmental Committee on Standardization of Petroleum Specifications.

SECTIONS

The Council had been considering since its February meeting the question of financial support of the Sections by the Society. In accordance with recommendations of the Sections Committee, it was decided at the April meeting not to change the amounts annually appropriated by the Society to the Sections, but to authorize the Sections in emergencies or in case of extraordinary expense to solicit donations from individuals and companies. The maximum amount to be accepted from any individual or company was fixed at $500 and the total amount to be so received by any Section during one year was set at $3,000. In the event of a Section accepting donations, the amounts and names of all donors are to be reported to the Council. It is not felt that the solicitation of funds in this way should be encouraged, but the Council is of the opinion that in case of unusual expense the Sections should be permitted to use their own good judgment in this connection within the limits stated.

OBITUARIES

BRUNO DAHL, works manager for A.-B. Abo Jernmanufaktur och Waggonfabrik O.-Y., Abo, Finland, died in November, 1920, of pneumonia, aged 36 years. He was born Nov. 3, 1885, at Helsingfors, Finland, and was graduated in 1911 from the Technical University of Finland with the degree of master of mechanical engineering.

From Sept. 1, 1905, to May 10, 1915, his practical experience was inclusive of machine-shop work, assembling and testing gasoline and Diesel marine engines and drafting for various foreign and domestic firms. He was chief draftsman for the Pittsburgh Model Engine Co. and engineer for the automotive department of the Standard Steel Car Co., both of Pittsburgh, from May, 1915, to about July 1, 1919, when he went abroad. His work at Abo consisted of the designing of engines and transmissions and specialization in the problems of the gasoline and kerosene internal-combustion engine. He was elected to Member grade in the Society, Dec. 10, 1919.

ROBERT J. DU BARRE, assistant manager of sales for the Geuder, Paeschke & Frey Co., Milwaukee, died April 20, 1921, aged 34 years. He was born Jan. 7, 1887, at St. Paul, Minn., and following his High School course attended the Milwaukee School of Enginering for 3 years.

From 1904 to 1908 he was a draftsman in the engineering department of the Wisconsin Telephone Co. and was chief draftsman for the company from 1908 to 1912.

For several years preceding September, 1912, he was in charge of the maintenance and operation of its motor-truck fleet. From Sept. 1, 1912, to 1915, he occupied an executive position relating to purchasing, motor sales and engineering, with the Falls Machine Co., Sheboygan Falls, Wis., and left this firm to form a connection with the Geuder, Paeschke & Frey Co. which he continued until his death.

He was held in high esteem by his friends and business associates, because of his attractive personality and on account of his engineering and business ability. He was elected to Associate Member grade in the Society, June 23, 1913, and transferred to Member grade Oct. 17, 1913.

HOWARD M. JOHNSON, manager of the rebuilt truck department of the Mack International Motor Truck Corporation, Los Angeles, Cal., died Feb. 25, 1921, aged 34 years. He was born June 29, 1887, in New York City and was educated at the Polytechnic Institute of Brooklyn and Columbia University.

In 1910 he was employed by the Locomobile Co. at Boston as a machinist and salesman. He severed this connection May 10, 1917, to enter the United States Navy as a chief machinist and gas-engine specialist, being assigned later to Submarine Chaser No. 417 as its commanding officer and remaining in the naval service until Jan. 13, 1919. For a short period following this he was marine machinist of the Southwestern Shipbuilding Co., San Pedro, Cal., and from June, 1919, to December, 1920, was a transportation engineer detailed on fleet advisory work in motor-truck transportation for Harold L. Arnold, Los Angeles, Cal., leaving this position to go with the Mack International Motor Truck Corporation.

During his career he collected considerable engineering data on automobile and marine gas engines, in connection with his practical machine-shop experience and naval engineering test work. He was elected to Associate Member grade in the Society, Nov. 22, 1920.

Dr. EDWARD B. ROSA, chief physicist of the Bureau of Standards, died suddenly in his office at Washington on May 17. He was born in Rogersville, N. Y., Oct. 4, 1861. His education included a course at Wesleyan University, from which he was graduated in 1886 with the degree of bachelor of science, and post graduate work at Johns Hopkins University from which he received the degree of doctor of philosophy in 1891. After serving as professor of physics at Wesleyan from 1891 to 1902, he became physicist at the Bureau of Standards. The degree of doctor of science was conferred upon him in 1906 by Wesleyan University. In 1910 he became chief physicist of the Bureau.

Dr. Rosa did notable work in the scientific field, particularly in electrical research. Subsequently to the entry of this country into the war he developed a number of scientific instruments which were of great value to the American Expeditionary Force. He also invented industrial plant safety devices and was active in the establishment of the aircraft safety code.

ACTIVITIES OF THE SECTIONS

RECENT elections by the Sections have resulted in the selection of the following members to serve on the Annual Nominating Committee of the Society for 1922:

	Member	*Alternate*
Boston	L. W. Rosenthal	Ira D. Shaw
Buffalo	H. R. Corse	J. T. R. Bell
Cleveland	A. E. Jackman	C. S. Pelton
Dayton	Thomas Midgley, Jr.	John H. Hunt
Detroit	Russell Huff	C. C. Hinkley
Indiana	W. G. Wall	Mark A. Smith
Metropolitan	Harold W. Slauson	M. C. Horine
Mid-West	Foree Bain	William O. Olson
Minneapolis	A. W. Scarratt	None
Pennsylvania	F. M. Germane	Edward L. Clark
Washington	H. C. Dickinson	W. S. James

The alternate in each case is authorized to act only in the absence of the first designated committeeman. In addition to these men there are elected at the business session of the Semi-Annual Meeting three members of the Society at large who with the 11 representatives of the Sections constitute the Committee. The President and the Secretary of the Society are ex-officio members of the Committee, but it has not been the custom for them to vote.

PROPOSED FALL MEETINGS

An earnest effort will be made to improve the quality of papers and to increase the attendance at Section meetings by planning the schedules a full year in advance. This has proved successful in the case of the Minneapolis Section and with the sections of other engineering societies. Arrangements for papers will be made well in advance of their presentation and so far as possible preprints made so that members of the Sections may have time to read the papers in advance of their presentation. Under these circumstances the authors can give at the meetings short abstracts of their papers, allowing more time for discussion. More members should be able to take part in the discussions and the character of the discussions should also be improved since it will be possible for the members to be prepared to discuss the papers instead of being compelled to make extemporaneous remarks.

The Mid-West Section has already outlined a program for six sessions on the fundamentals of internal-combustion engines, covering the laws of thermodynamics, the principles of carburetion, combustion phenomena and thermal and mechanical losses.

RECENT MEETINGS

H. H. Platt spoke on May 6 before the Washington Section at the Cosmos Club on the design of piston-rings. He showed mathematically and by test results that leakage through the gap of a piston-ring is of slight importance compared with the leakage around the wall of the cylinder. Engineers of various piston-ring manufacturers were present and entered into a lively discussion on the advantages and disadvantages of the different methods of manufacture. Moving pictures were shown and an interesting description given by John A. Allen of the method of extinguishing difficult fires by a chemical foam.

The Indiana Section meeting of May 5 was taken up largely with the perfecting of plans for the Section's participation in the program of the Summer Meeting. Due to the fact that the Semi-Annual Meeting was held this year in Indiana, the Section spent considerable time and effort in contributing to its success by arranging an Indiana Night program. Those who were at the meeting will appreciate the work done by the Indiana members.

The Mid-West Section gave a party on May 13 and in recognition of the desire of the members to conserve their financial resources for the attractions at the Summer Meeting, the members and guests ate, smoked, and were entertained at a price which was "back to normalcy." Over 60 were present.

The Minneapolis Section held its concluding spring meeting on May 4. William Kidder spoke on airplane patrol, Russell Greer talked on Trucking in the Twin Cities, and Phil Overman gave an account of the use of tractors in the logging woods.

The Dayton Section fittingly concluded its excellent first season's program with a talk by H. L. Horning.

Car-theft prevention and its relation to automobile insurance received the attention of the Metropolitan Section at its meeting on May 19. The Cleveland Section on the following night considered the subject of automobile insurance in general. Figures recently quoted by one of the insurance companies indicate that in many instances full insurance costs annually more than one-quarter of the value of the car. Practically all the losses covered by insurance are preventable. A fuller account of these important meetings will appear in a subsequent issue of THE JOURNAL.

TRANSPORTATION IN DIFFERENT COUNTRIES

TRAFFIC in new countries always follows the waterways. When the pioneers begin to branch from these lines of portage, then begins the development of the highways. There is no more fascinating and interesting subject in the history of civilization than the development and use of highways. The framers of the Constitution of the United States recognized that transportation and communication were of primary and fundamental importance, if the union which they were creating was to continue, and made provision for the building of highways known as post roads.

Up to the time of the advent of the railroads there was in this country a notable development of the highways and there still remain some of these, such as the post road connecting Boston and New York, the National Pike from Baltimore to the Ohio River, the Philadelphia-Pittsburgh Pike and others. Over these highways there flowed from the East over the Allegheny Mountains an enormous amount of traffic, and those sections of the country which were reached by these highways were naturally the earliest to develop.

Railroads were looked upon as substitutes for these highways and for several generations the country lost interest in the development of a national highway system, but the advent of the automobile provided a new means of transportation for passengers and freight and there immediately arose an insistent demand for better roads.

The cost of transportation in different countries in 1902 is given in the following table:

Countries	Per ton-mile	Wages per day
China	$0.1000	$0.10
Japan	0.0500	0.23
Russia	0.0220	0.34
Italy	0.0240	0.26
Austria	0.0225	0.50
Germany	0.0150	0.90
France	0.0190	0.80
England	0.0260	1.04
United States	0.0069	2.60

—F. L. Bishop.

CURRENT STANDARDIZATION WORK

THE eight Division meetings held during April and the Standards Committee Meeting on May 24 brought to a close the active work of the Standards Committee for the first half of 1921. Reports of 10 Divisions covering 26 recommendations were submitted at the Standards Committee Meeting, copies of which were sent to the Society members in pamphlet form prior to the meeting. The report of the Standards Committee as approved by the Council and at the Society Meeting will be published in the July issue of THE JOURNAL, together with the discussion.

A large amount of Division and Subdivision work is, however, in progress which will be carried on during the coming months although it is expected that the vacation season will retard the work somewhat.

AXLE AND WHEEL DIVISION

An Axle and Wheel Division has been appointed by the Council to consider the standardization of axles and wheels and parts germane thereto. G. W. Dunham has accepted the chairmanship, the other members appointed being C. C. Carlton, vice-chairman, T. V. Buckwalter, R. J. Burrows, J. Coapman, C. S. Dahlquist, F. W. Gurney, G. L. Lavery, A. M. Laycock, C. T. Myers, A. L. Putnam, J. G. Swain, G. J. Thomas and H. Vanderbeck. This newly formed Division will cooperate with the Truck Division on the wheel-hub standardization work which the Truck Division has carried on during the last two years, having submitted a report on motor-truck front hubs at the Semi-Annual Meeting of the Standards Committee. The eventual standard, will, if feasible, include hub dimensions for passenger-car front-axle hubs and passenger-car and motor-truck rear-axle hubs. Other subjects before the Division are brake-drums, differential gears, emergency rim clamps and metal wheel felloes. A Subdivision consisting of R. J. Burrows, chairman, H. S. Jandus and representatives of pressed steel parts manufacturers has been appointed to consider the subject of brake-drums. A tentative report drawn up by the Truck Division during 1920 will be used as a basis for the Subdivision work.

ELECTRICAL EQUIPMENT DIVISION

A subdivision has been appointed to consider the subjects of flexible steel and non-metallic conduit, consisting of B. M. Leece, chairman, W. S. Haggott, Ernest Wooler and representatives of the National Metal Molding Co. and the American Circular Loom Co. The work of the Subdivision will be to bring the present S. A. E. Standard for flexible steel conduit into accord with present insulated-cable practice and to formulate recommendations for non-metallic conduit as a large amount of circular loom is now being used for automobile wiring.

The Division has under consideration the desirability of standardizing the distance from the end of the coupling tongue to the end of the distributor body for the Type *B* S. A. E. Standard timer-distributor, page B16, S. A. E. HANDBOOK. Final action will be based on comments received in answer to a general letter that will be sent out shortly

The Division has been requested to consider the desirability of shortening the present shaft length of the generator flange mounting to permit decreasing the overall distance from the face of the generator flange to the inside of the gearcase cover as in some applications the gearcase cover interferes with the fan. As the present standard is widely used, final action will be based on comments received through circularization.

The Division has approved the recommendation of the S. A. E. Patent Committee that the illustration of the present S. A. E. Recommended Practice for starting-motor barrel mounting, page B20, S. A. E. HANDBOOK, be redrawn so as to indicate only the actual dimensions standardized. As it is considered good engineering practice to cover tractor and farm engine spark-plugs with non-metallic molded hoods to make them waterproof, when the engine is not protected by a hood or other housing, the Division has, at the request of the Stationary Engine Division, appointed a Subdivision to obtain data and prepare a report based on present practice.

A Subdivision has been appointed to consider the further standardization of magneto mountings with special reference to mountings for stationary-engine, isolated-electric-lighting-plant and tractor magnetos. Interchangeability of magnetos is considered one of the important problems before these industries at the present time. Members of the Subdivision are F. W. Andrew, chairman, A. D. T. Libby, J. M. Edwards, representing the Stationary Engine Division, W. F. Bogerd, representing the Tractor Division and F. L. Tubbs, representing the Isolated Electric Lighting Plant Division.

ENGINE DIVISION

The Division has discussed in detail the advisability of consolidating the flange dimensions of the ½ and ⅝-in and the ¾ and ⅞-in. nominal carbureter sizes, although retaining the same actual inside diameters as at present. As this modification will affect the design of carbureters and manifolds, the final report of the Division will be based on the results of circularizing.

The Subdivision on Engine Testing Forms is studying the present standard engine testing forms with a view to extending them to permit adding data on lubricants and will also incorporate several suggestions which have been received in connection with the present forms.

The Subdivision on Fan Belts and Pulleys recently appointed consists of Louis Schwitzer, chairman, C. E. Jacobs, H. A. Weaver, G. A. White and K. F. Walker. At the meeting of the Engine Division on April 18 held jointly with the members of the Subdivision on Fan Belts and Pulleys it was recommended tentatively that the included angle for V-belts, both rubber and leather, and pulleys should be 40 deg. This angle was recommended after a careful review of V-belt practice which varies from 28 to 45 deg., and as it was understood that for the smaller angles the wear on the belts is excessive and that for the larger angles the heavier belts cause excessive slipping at high speed owing to their greater weight and the resulting centrifugal force.

It is proposed to revise the present S. A. E. Standard for fan belts and pulleys by omitting the ¾ and the 1¾-in. widths, as they are used to a very limited extent, and adding the 2½ and 3-in. widths, which are intended to meet the requirements for heavy truck and tractor engine installations.

As it is considered that standardization of the fan driving pulley diameters would be of material assistance in designing and installing fan equipment, the tentative proposal given in the following table was adopted

PROPOSED FAN DRIVING PULLEY DIAMETERS

Number of Cylinders	Ratio of Fan to Engine Speed	Pulley Diameter, in.
6	1	3, 3½, 4
4	1½	5½, 6 , 6½

Radius of crown to be 6½ in. for all pulley sizes.

Pulley diameters vary considerably in practice and their standardization will permit the fan manufacturers to layout the driven pulley for practically any fan speed desired, and it will facilitate also the determination of the diameter of the driven pulley for various fan installations.

The tentative recommendations applying to fan belts and pulleys and fan hubs will be circularized among the manufacturers interested for comment before final action is taken by the Division

The following recommendation was approved by the Standards Committee at its January meeting:

> Mufflers shall vary in diameter and in length by even inches and shall be supported by hands extending around the circumference.

Owing to the large number of negative votes cast against the adoption of this proposal by Members of the Society, the Council referred the recommendation back to the Engine Division for further consideration. A Subdivision consisting of M. J. Steele, chairman, R. J. DuBarre, Virgil Oldberg and Captain Seig has therefore been appointed to review the recommendation. The Subdivision will consider the suggestion to standardize muffler capacity with respect to piston displacement, as well as the standardization of the outside diameters of the exhaust and muffler outlet-pipes, the outside diameters and lengths of mufflers and the location and size of the through-bolts for assembling them.

Non-Ferrous Metals Division

The subjects awaiting consideration by the Non-Ferrous Metals Division have been assigned to Subdivisions on Aluminum Alloys, Wrought Brasses and Bronzes. Die-Casting Alloys and Miscellaneous Non-Ferrous Metal Alloys, the Chairmen of which are Zay Jeffries, W. B. Price, Charles Pack and H. C. Mougey respectively. Subjects under consideration include brazing brasses, hard and soft solders, aluminum sheets, rod and tubing, Tobin-bronze tubing, brass and bronze spring-wire, brass forging-rod, die-casting alloys and babbitt.

Parts and Fittings Division

The Division has given considerable attention to the feasibility of formulating specifications for testing felt, but has come to the conclusion that it is impracticable to do so. The subject has therefore been tabled indefinitely.

The original tentative recommendation of the Subdivision on Horn Mountings specified an outside mounting on the running-board of the car, an engine mounting for which two studs were considered sufficient, with an alternate bracket which would permit mounting the horn under the head of one of the cylinder cap studs, and a dash mounting which is being used at the present time by a few companies. As it was the consensus of opinion that it would be difficult to specify a location on the cylinder block that would permit of sufficient clearance on all makes of cars, the subject has been tabled indefinitely.

C. W. Spicer, who was assigned the work of formulating specifications for taper and straight serrated-shaft fittings, submitted a tentative recommendation for straight serrated-shaft fittings at the April 19 meeting of the Division. The recommendation was not based on theoretical dimensions but upon the dimensions working from the pitch-line in somewhat the way screw-threads are dimensioned. A recommendation for the taper serrated-shaft fittings is being worked out along the same principle. The two proposals will be referred to manufacturers for comment before final action is taken by the Division.

A Subdivision report has been submitted by E. W. Hart covering revisions of the present S. A. E. Standard for lock washers, page C5, S. A. E. Handbook. Three series of lock washers are recommended, "Standard," "Special Light" and "Special Heavy," for both S. A. E. Standard bolts and standard machine-screws with either round or fillister heads. The report will be circularized among the automobile and parts manufacturers and comments received referred to members of the Parts and Fittings Division for consideration.

The Transmission Division has recommended that the present S. A. E. Standard for taper fittings with plain or slotted nuts be revised by the addition of a note reading, "The center-line of the cotter-pin hole shall be 90 deg. from the position of the keyway as shown on the drawing," because many times question arises as to the location of the cotter-pin hole with respect to the position of the keyway.

The Division is working on the standardization of flexible discs for magneto-couplings and universal-joints. Although flexible-disc universal-joints are considered to be in a stage of evolution, it is thought that standardization will do much to decrease the large number of mold sizes necessary at the present time and facilitate replacements and interchangeability.

PRINCIPLES UNDERLYING ELECTRICAL IGNITION

(*Concluded from page* 576)

Professor Bailey:—It depends upon the condition of the electromotive force of the coil and other things. In general, if a coil gives a high enough electromotive force, a somewhat wider gap will probably give more energy. Whether that energy is more effective or not, I do not know. I have stated that I believe that if the gap is widened and the energy distributed over a larger volume, it has not much more power, if any. On the other hand, making the gap too short will interfere more or less with the ignition. I understand that a gap can be so short that there will be no ignition because there is not enough spark.

E. H. Vincent:—Why do ordinary commercial generators have a greater output cold than warm? Is it caused by resistance?

Professor Bailey:—Yes, the resistance of the generator increases very much as it heats up. The rise of temperature is in the neighborhood of perhaps 40 deg. cent. (104 deg. fahr.). The generator becomes hotter and the resistance of copper wire changes 0.4 per cent to the degree. That means a change of about 16 per cent, which is enough to affect the output very materially. It cuts down the shunt current about 14 per cent and at the same time increases the armature resistance 16 per cent; it is harder to get the current through and so there is a very decided decrease of it.

Mr. Barthel:—Is it possible to proportion the winding of the coil so that it will be in exact proportion with the deflection of the spring or vibrator, so that practically synchronous action is obtained? The consensus of opinion seems to be that it is not possible to accomplish that, although one person claimed that he had accomplished it; in other words, by putting additional windings on the core, or the coil, to get an action so that practically the pull will be proportional to the spring deflection.

Professor Bailey:—I think it would be extremely difficult, if not impossible, to do that.

Mr. Barthel:—That seemed to be the consensus of opinion of all the electrical engineers and the coil-manufacturers, and yet it was claimed that this result was accomplished.

Professor Bailey:—The pull would run up very rapidly as the iron armature approached the core, and the spring tension would not run up so rapidly.

Mr. Barthel:—I can understand how an approximation of it would be possible.

Professor Bailey:—I do not see that it could be done, except approximately, as you say, because the laws are more or less radically different. With a solenoid it would not be very difficult to do it. There is a considerable range wherein the pull is represented by a straight line and it might be possible to do it by a combination.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between April 9 and May 10, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ALEXON, JOHN M. (E S) 106 First Street, South, *Virginia, Minn.*

APOR, EMIL L. (J) Cotton, Neill & Co., *Honolulu, T. H.,* (mail) 1278 Punchbowl Street.

ARMINGTON, A. P. (M) superintendent and tractor engineer, Euclid Crane & Hoist Co., *Euclid, Ohio.*

AUCOCK, HERBERT (A) proprietor, Herbert Aucock Co., 185 Columbus Avenue, *Boston.*

BLAKE, E. A. (J) in charge of experimental department, Transport Truck Co., *Mount Pleasant, Mich.*

BRADY, L. J. (A) assistant manager, Nash Sales Co., 2000 South Michigan Avenue, *Chicago.*

BROWN, GORDON (M) engineer, Condensite Co. of America, *Bloomfield, N. J.,* (mail) 79 North Mountain Avenue.

BRYANT, WILLIAM L. (M) president, Bryant Chucking Grinder Co., *Springfield, Vt.*

BUSER, WILLIAM CHARLES (J) shop engineer, Midwest Engine Co., *Indianapolis,* (mail) 1819 Commerce Avenue.

BUTTNER, EDGAR LOUIS (E S) student, University of California, *Berkeley, Cal.,* (mail) 1522 Walnut Street.

GALLAGHER, FRANK J. (A) assistant to fire marshal, City of Philadelphia, *Philadelphia,* (mail) 6101 Columbia Avenue.

CASTRICONE, JOHN A. (M) factory superintendent, Pittsburgh Model Engine Co., *Pittsburgh,* (mail) 537 Turrett Street, East End.

CHAILLIEY, GEORGE A. (A) American manager, Panhard & Levassor, 19 Avenue de Troy, *Paris, France,* (mail) 24 rue Vignon.

COBB, E. E. (A) manager of sales and service, United States Malleable Iron Co., *Toledo.*

COLE, W. F. (A) chief inspector, automobile body department, Osgood Bradley Car Co., *Worcester, Mass.,* (mail) 30 Rockdale Street.

COLEMAN, CHARLES H. (M) assistant mechanical engineer, power plant section, Bureau of Standards, *Washington,* (mail) 1329 H Street, Northwest.

DALEY, FRANK R. L. (A) chief inspector, Northway Motors Corporation, Natick, Mass., (mail) 183 West Central Street, *West Natick, Mass.*

DAVIS, HOWARD LA MONTE (A) sales engineer, Connecticut Telephone & Electric Co., Meriden, Conn., (mail) 1734 Ridge Avenue, *Evanston, Ill.*

DELAVAL-CROW, THOMAS CLIVE (M) chief engineer, New Departure Mfg. Co., *Bristol, Conn.,* (mail) 132 Stearns Street.

DE PUY, CLARENCE E. (M) professor of mechanical engineering, Lewis Institute, Chicago, (mail) 411 North Elmwood Avenue, *Oak Park, Ill.*

DESONIA, LLOYD J. (E S) student, automotive department, Virginia High School, *Virginia, Minn.,* (mail) 412 First Street, North.

DE SMET, EDGARD C. (J) Handley-Knight Co., *Kalamazoo, Mich.,* (mail), 132 East South Street.

DIFFENBAUGH, HARRY (S M), *Camp Devens, Mass.*

EATON, WILLIAM S. (M) body engineer and director of body department, du Pont Motors, Inc., Moores, Pa., (mail) 915 North Fourth Street, *Reading, Pa.*

FORDYCE, THOMAS NEWTON (A) district representative, Willard Storage Battery Co., Cleveland, (mail) 1380 Bush Street, *San Francisco.*

GAGE, OSCAR THOMAS (A) assistant general foreman, Sheridan Motor Car Co., *Muncie, Ind.,* (mail) 1420 West Ninth Street.

HARRSCH, WILLIAM GEORGE (A) president, Highway Truck Corporation, 100 West Garfield Boulevard, *Chicago.*

HERMAN, FRED WELD (E S) student, University of California, *Berkeley, Cal.,* (mail) Cottage 3, Campus.

HERMAN, BRUNO (M) dean and mechanical engineer, California School of Mechanical Arts, 16th and Utah Streets, *San Francisco.*

HOLBROOK, FRANK (M) chief inspector, Russel Motor Axle Co., North Detroit, (mail) 2331 Grand Boulevard East, *Detroit.*

HOOD, CLIFFORD F. (A) superintendent, electric cable works, American Steel & Wire Co., *Worcester, Mass.* (mail) 738 Main Street.

HUBBARD, HENRY M. (A) automotive designer, Cleveland Ordnance Engineering Office, *Cleveland,* (mail) Suite 18, 2035 East 96th Street.

HUMMER, CHARLES IGNATZ (M) chief engineer, Vreeland Motor Co., Inc., 407 Elizabeth Avenue, *Newark, N. J.*

JONTZ, G. F. (M) chief inspector, tractor works, Moline Plow Co., *Rock Island, Ill.,* (mail) 806 44th Street.

KAZEY, ARTHUR R. (M) assistant chief engineer, Ross Gear & Tool Co., *Lafayette, Ind.,* (mail) 806 Cincinnati Street.

KELLEY, E. A. (A) sales representative, Splitdorf Electrical Co., Newark, N. J., (mail) 1295 Woodward Avenue, *Detroit.*

KNAPP, ARCHER L. (M) automobile body engineer, Packard Motor Car Co., *Detroit,* (mail) 2156 Cadillac Avenue.

KORN, ALEX A. (A) chief engineer, Morand Cushion Wheel Co., *Chicago,* (mail) 1830 West 34th Place.

LAGUIRE, RAYMOND F. (J.) laboratory assistant, Joseph Tracy, New York City, (mail) 89 Prospect Place, *Rutherford, N. J.*

LAZARNICK, NATHAN (A) proprietor, Commercial Photography, 246 West 42nd Street, *New York City.*

LEET, ALBERT B. (M) chief draftsman, Rockford Drilling Machine Co., *Rockford, Ill.,* (mail) 1317 North Main Street.

LINCOLN, WILLIS C. (A) engineer, National Railway Appliance Co., New York City (mail) 70 John Street, *Belleville, N. J.*

LINEK, JOSEPH, JR. (J) foreman, J. Linek, *Maspeth, N. Y.,* (mail) 5 Elm Street.

LINNEY, WILLIAM A. (A) foreman, dynamics laboratory, Aluminum Manufactures, Inc., *Cleveland,* (mail) 2140 Broadview Road.

MCKENNA, A. W. (A) superintendent, Osgood Bradley Car Co., *Worcester, Mass.,* (mail) 465 Park Avenue.

MCMAHON, JAMES J. (J) in charge of engineering, Mercury Motors Corporation, 5929 Baum Boulevard, *Pittsburgh.*

MALOON, EARL B. (J) draftsman, C. L. Best Gas Tractor Co., San Leandro, Cal., (mail) 2587 35th Avenue, *Oakland, Cal.*

MIDGLEY, ALBERT HENRY (F M) chief engineer and advisor, C. A. Vandewell & Co., Ltd., Acton, London, West, (mail) Fairfield, Harefield Road. *Uxbridge, England.*

NEWTON, M. H. (A) advertising manager, White Co., *Cleveland,* (mail) 6611 Euclid Avenue.

NICHOLSON, DONALD J. (J) experimental engineer, International Harvester Co., Chicago, (mail) 3820 California Street, *Omaha, Neb.*

NORELIUS, EMIL F. (M) consulting engineer, 430 Andrus Building, *Minneapolis.*

OLLEY, MAURICE (M) engineer, Rolls-Royce of America, Inc., *Springfield, Mass.* (mail) 46 Rockland Street.

OUTCALT, WILLIAM J. (J) head of standard parts department, General Motors Corporation, *Detroit,* (mail) 6003 McClellan Avenue.

OVERMAN, PHIL N. (A) sales engineer, Hyatt Roller Bearing Co., Chicago, (mail) 10 South 10th Street, *Minneapolis.*

PITTMAN, KNOWLES (A) sales manager, Electric Steel Co., Chicago, (mail) 882 Elm Street. *Winnetka, Ill.*

POPPE, PETER A. (F M) technical director, White & Poppe, Ltd., *Coventry, England,* (mail) Logna, Warwick Avenue, Earlston.

PRATT, JAMES M. (A) assistant to general manager, Northway Motors Corporation, *Natick, Mass.* (mail) 81 Speen Street.

REDFIELD, C. S. (M) manager, development department, Dunlap Tire & Rubber Corporation of America, *Buffalo, N. Y.* (mail) 48 Irving Place.

RUTLEDGE, C. B. (A) proprietor and manager, Auto Equipment Service Co., *Memphis, Tenn.,* (mail) 27 North Belvedere Boulevard.

SANDERS, WILLIAM E. (A) assistant engineer and general superintendent, Standard Automotive Corporation, *Mooresville, Ind.*

SEYMOUR, GLEN F. (M) trouble investigator and layout man, Cleveland Automobile Co., *Cleveland* (mail) Hotel Regent.

SAUER, HERBERT F. (A) branch manager, Electric Storage Battery Co., Philadelphia, (mail) 2325 Chester Avenue, *Cleveland.*

SHIDLE, NORMAN G. (A) editorial staff, *Automotive Industries, New York City,* (mail) 880 West 180th Street.

SNYDER, FLOYD E. (A) chief inspector, Stutz Motor Car Co., *Indianapolis,* (mail) 1301 Parker Avenue.

STEADMAN, CLAUDE A. (J) chassis and motor layout, C. H. Wills & Co. *Marysville, Mich.* (mail) Box 41.

STEWART, JAMES L. (A) vice-president and general manager, Thomart Motor Co., *Akron, Ohio.*

THOMAS, S. J. (A) sales engineer, Canton Rim Co., Louisville, Ohio (mail) 616 Maryland Avenue, S. W. *Canton, Ohio.*

THOMS, LOUIS (M) engineer, truck division, Advance-Rumely Co., *Battle Creek, Mich.*

VANCIL, E. D. (J) designer, Garford Motor Truck Co., *Lima, Ohio,* (mail) 468 East Pearl Street.

WALKER, GILBERT DUNSTAN (M) production manager and engineer, Nofalt Motor Products Co., Inc., Holyoke, Mass., (mail) 14 Charter Oak Avenue. *Hartford, Conn.*

WASSERFALLEN, C. F. (M) factory manager and engineer, Detroit Carrier & Mfg. Co., 8635 Covant Road, *Detroit.*

WEINSTEIN, HARRY (E S) student, Pratt Institute, *Brooklyn, N. Y.,* (mail) 1764 Bergen Street.

WEISSINGER, HORACE L. (M) superintendent, automobile body department, Osgood Bradley Car Co., *Worcester, Mass.,* (mail) 614 West Boylston Street.

WELLS, D. W. (M) vice-president and general manager, Electric Steel & Forge Co., Cleveland, (mail) 1205 Overlook Road, *Lakewood, Ohio.*

WHITE, EARL A. (M) technical editor, *Farm Implement News,* Masonic Temple, *Chicago.*

WILLIAMS, CHESTER P. (A) sales engineer, Northway Motors Sales Co., Boston, (mail) 33 Florence Street, *Natick, Mass.*

WILLIAMS, J. J. (M) general production superintendent, Federal Rubber Co., Cudahy, Wis., (mail) Apartment 611, 203 Juneau Avenue, *Milwaukee.*

Applicants *for* Membership

The applications for membership received between April 23 and May 19, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ALLEN, GEORGE B., chief engineer, Liberty Motor Car Co., *Detroit.*

ANDERSON, A. E., garage foreman, Standard Oil Co., *Spokane, Wash.*

BARRETT, FRANK C., designer, Southern Motor Corporation, Ltd., *Houston, Tex.*

BARRETT, W. F., vice-president, Prest-O-Lite Co., Inc., *New York City.*

BARTLETT, LINTON G., vice-president and chief engineer, O'Connell Motor Truck Co., *Waukegan, Ill.*

BEAUDRY, PIERRE, student, Massachusetts Institute of Technology, *Cambridge, Mass.*

BLACK, CHARLES F., production manager, Osgood Bradley Car Co., *Worcester, Mass.*

BLACKMORE, LLOYD, patent attorney, General Motors Corporation, *Detroit.*

BLAIR, ROBERT, aeronautical engineer, *Elgin, Ill.*

BLUM, LOUIS E., JR., machine designer, Splitdorf Electrical Co., *Newark, N. J.*

BRADLEY, JOHN E., president, Osgood Bradley Car Co., *Worcester, Mass.*

BRADLEY, JOHN J., JR., chief follow man for factory, Continental Motors Corporation, *Detroit.*

BREWER, JOHN W., manager pricing department, International Motor Co., *New York City.*

BROPHY, J. W., assistant production superintendent, Remy Electric Division, General Motors Corporation, *Anderson, Ind.*

BUCHEN, WALTHER, advertising executive, J. Walter Thompson Co., *Chicago.*

BUXTON, H. B., merchant, Suipacha 602, *Buenos Aires, Argentine, South America.*

CARPENTER, MANSON C., sales engineer, Holley Carburetor Co., *Detroit.*

CARR, MOSES FRANCIS, assistant general manager, Carr Fastener Co., *Cambridge, Mass.*

CHASE, EUGENE P., assistant parts manager, Locomobile Co. of America, *Bridgeport, Conn.*

DARNELL, REX C., assistant chief engineer, Northway Motor & Mfg. Co., *Detroit.*

DEL PRADO, ALBERT, mechanic, Franclin Car Co., *Jersey City, N. J.*

DILGER, FRANK P., president, Checker Taxi Co., *Chicago.*

DODSHON, FRED G., by-products manager, General Motors Corporation, *Detroit.*

DONAHUE, F. M., student, International Correspondence Schools, *Scranton, Pa.*

DOYLE, JOSEPH A., sales and service department, Stromberg Motor Devices Co., *Chicago.*

DWYER, ROBERT E., director of motor buses, Commissioners of Lincoln Park, *Chicago.*

EDELEN, JAMES L., engineering department, Moon Motor Car Co., *St. Louis.*

FEERMSTER, DAVID R., assistant chief engineer, Bock Bearing Co., *Toledo.*

FORD, FRED H., manager of roadlighter department, C. A. Shaler Co., *Waupun, Wis.*

GARDINER, A. W., secretary, Trimming Supply Co., *Cleveland.*

GAUTHIER, EDWARD, mechanical draftsman, Holt Mfg. Co., *Stockton, Cal.*

GIBSON, ALLEN W., special representative, Prest-O-Lite Co., Inc., *New York City.*

GINSBERG, SAMUEL, partner, Ginsberg Motor Co., *Montreal, Canada.*

GOLDBERGER, ERNEST, tractor designer, Detroit Pressed Steel Co., *Detroit.*

GOSSLING, W. E., storage battery engineer, Prest-O-Lite Co., *New York City.*

GRUENBERG, WALTER H., student, Tri-State College, *Angola, Ind.*

HANSON, WALTER M., sales engineer, Geuder Paeschke & Frey Co., *Milwaukee, Wis.*

HARMON, C. O., sales engineer, Cleveland Engineering Laboratories, *Cleveland.*

HASTINGS, WARREN B., editor, Ontario Motor League, *Toronto, Canada.*

HEWITT, CLARENCE C., special factory representative, Tide Water Oil Sales Corporation, *Detroit.*

HOOVEN, ALBERT M., secretary and treasurer, Meteor Motors Corporation, *Philadelphia, Pa.*

HOWELL, HORACE L., manager of research, National Railway Appliance Co., *New York City.*

HUEBNING, C. L., assistant engineering inspector, Mitchell Motors Co., Inc., *Racine, Wis.*

HULBERT, L. G., metallurgist, Locomobile Co. of America, *Bridgeport, Conn.*

HULL, NAT. D., manager, Automatic Visible Pump Co., *Memphis, Tenn.*

JOHNSON, CHARLES B., general sales manager, Penberthy Injector Co., *Detroit, Mich.*

KALTWASSER, C. M., treasurer and general manager, Salisbury Axle Co., *Jamestown, N. Y.*

KEITH, EBEN F. S., vice-president, Osgood Bradley Car Co., *Worcester, Mass.*

KERSHNER, VIRGIL H., engineer, Oklahoma Gas & Electric Co., *Oklahoma City, Okla.*

KIMBALL, EARL W., vice-president, Ostendorf Motor Car Corporation, *Buffalo, N. Y.*

KINGSTON, CHARLES T., manager, John Brennan & Co., *Detroit.*

KOPPER, FREDERICK, JR., mechanical engineer, Bureau of Standards, *Washington.*

LANSING, RAYMOND P., chief engineer, Bijur Motor Appliance Co., *Hoboken, N. J.*

LARKIN, WALTER P., superintendent, jobbing division, Bock Bearing Co., *Toledo.*

LAUGHLIN, S. L., chief engineer, Peters Machine & Mfg. Co., *Cleveland.*

LEE, ROY E., chief draftsman, Russel Motor Axle Co., *Detroit.*

LINDSAY, H. O., chief engineer, department of internal-combustion engines, Pure Oil Co., *Minneapolis.*

LOCKWOOD, F. R., chief engineer, A. J. Detlaff Co., Inc., *Detroit.*

LOLLEY, WILLIAM H., export manager, Standard Parts Co., *Cleveland.*

LOVE, HORACE, Eastern sales manager, Parish Mfg. Corporation, *Reading, Pa.*

LYDECKER, J. M., engineer, Asch & Co., *New York City.*

MCALPIN, KENNETH, vice-president and general manager, Motor Products & Sales Co., *Seattle, Wash.*

MACDONALD, LACHLAN M., vice-president and general manager, Bryan Pattern & Machine Co., *Bryan, Ohio.*

MARKIN, MORRIS M., president, Markin Auto Body Corporation, *Chicago.*

MILLER, EDWARD J., chief draftsman, Allen Motor Co., *Columbus, Ohio.*

MIXSON, ROBERT E., motor mechanic inspector, Langley Memorial Aeronautical Laboratory, *Hampton, Va.*

MOORE, WHITLEY B., sales engineer, Timken Roller Bearing Co., *San Francisco.*

MUELLER, MAX M., superintendent, steering gear department, Borg & Beck Co., *Chicago.*

MUHLON, EDWARD, experimenting and testing on engines, H. D. Motors Corporation, *New York City.*

MURRAY, MAJOR MAXWELL, office, Chief of Field Artillery, *Washington.*

MURRAY, ROBERT R., mechanical superintendent, Provincial Highway Board, *Halifax, Nova Scotia.*

NAIDEN, JAMES H., director of laboratories, Prest-O-Lite Co., Inc., *Indianapolis.*

NATIONAL STEEL CAR CORPORATION, LTD., *Hamilton, Ont., Canada.*

NEIGH, JOSEPH R., director of service, Bessemer Motor Truck Co., *Grove City, Pa.*

NIELSON, MORITZ, mechanical engineer, Elgin Motor Car Corporation, *Argo, Ill.*

NORDSTRUM, G. W., secretary and treasurer, Aetna Ball Bearing Mfg. Co., *Chicago.*

NULL, JOSEPH F., general manager, Manufacturing Engineering Service, *Detroit.*

OBUCHOWSKI, ANTHONY, draftsman, Jaxon Steel Products, *Jackson, Mich.*

PENGILLY, H. EUGENE, mechanical engineer, motor carriage section, Ordnance Department, *Washington.*

PIERCE, J. OTIS, sales manager, Brown-Lipe Gear Co., *Syracuse, N. Y.*

PIERSON, LISLE A., service manager, Mack Motor Truck Co., *Hartford, Conn.*

POWERS, HARRY H., machine foreman, Remy Electric Division, General Motors Corporation, *Anderson, Ind.*

PROSPERI, A. G., service manager, Southern Oakland Co., *Atlanta, Ga.*

RAMSAY, LLOYD M., assistant superintendent of motor equipment, Charlotte branch, Standard Oil Co. of N. J., *Charlotte, N. C.*

REITER, R. H., manager, Perfection Piston Ring Co., *Ravena, Ohio.*

ROBINSON, L. G., sales and advertising manager, Bantam Ball Bearing Co., *Bantam, Conn.*

ROGERS, JAMES B., experimental engineer, Joy Ball Bearing Co., *Chicago.*

REAM, FRED H., inventor and developer of the National Snubber, National Steel Products Co., *Dayton, Ohio.*

SAWYER, ALBERT F., chief engineer, American Motors Export Co., *Jacksonville, Fla.*

SCHILLING, C. A., chief inspector, Yuba Mfg. Co., *Benicia, Cal.*

SCHUMANN, FRANK A., master mechanic, Willys Corporation, *Elizabeth, N. J.*

SHANNON, GEORGE A., chief draftsman, Paige-Detroit Motor Car Co., *Detroit.*

SHIPLEY, WILLARD J., instructor, Michigan State Auto School, *Detroit.*

SHRUM, A. T., chief draftsman, Walker Vehicle Co., *Chicago.*

SLIGO IRON STORE CO., St. Louis, Mo.

SMITH, HARRY G., assistant engineer, Holley Carburetor Co., *Detroit.*

SMITH, LAWRENCE V., student, Cornell University, *Ithaca, N. Y.*

SMITH, OSCAR A., superintendent, National Acme Co., *Cleveland.*

SMITH, ROY D., assistant chief engineer, Triumph Truck & Tractor Co., *Kansas City, Mo.*

SPEER, M. B., superintendent, automobile equipment service department, Westinghouse Electric & Mfg. Co., Springfield, Mass.

SPOHN, FRANK L., service engineer, Euclid Building, *Cleveland.*

SPRAY, JUDD W., district manager of sales, Timken Roller Bearing Co., *Canton, Ohio.*

STEESE, HEATON S., production manager, Daniels Motor Co., *Reading, Pa.*

STUART, CLARENCE C., sales engineer, Soss Mfg. Co., *Brooklyn, N. Y.*

THEARLE, ERNEST L., instructor in mechanical engineering, Sibley College, Cornell University, *Ithaca, N. Y.*

TONEY, C. B., JR., layout draftsman, Wichita Motors Co., *Wichita Falls, Tex.*

WALKLEY, F. H., chief engineer, Dayton Steel Foundry Co., *Dayton, Ohio.*

WARNOCK, T. E., truck engineer, Paige-Detroit Motor Car Co., *Detroit.*

WEED, HUGH H. C., vice-president and general manager, Carter Carburetor Co., *St. Louis.*

WERNEKEN, FRANK E., secretary and treasurer, John Brennan & Co., *Detroit.*

WOLFARD, MERL RUSKIN, engineer in charge of research laboratory, Hopewell Bros., *Watertown, Mass.*

WOLFE, CHASE W., manager, pneumatic truck tire department, Federal Rubber Co., *Cudahy, Wis.*

WORK, ROBERT VAN HORN, engineer, Baker Steam Motor Car & Mfg. Co., *Pueblo, Col.*

WRIGHT, THOMAS C., chief engineer, Standard Steel & Bearing, Inc., *Philadelphia, Pa.*

YAGLOGLOU, C. P., mechanical engineer, research laboratory of the American Society of Heating and Ventilating Engineers, *Pittsburgh.*

YOUNG, RAYMOND WILLIAM, student, Sheffield Scientific School, Yale University, *New Haven, Conn.*

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Personal Notes of the Members

Items regarding changes in business connections, promotions, etc., are desired from the membership for insertion in these columns. This will enable members to keep their friends informed of their whereabouts and will also assist in keeping the records of the Society up to date.

John R. Aude has resigned as service manager of the Maxwell-Chalmers Co., Brooklyn, N. Y., to accept a position as automobile engineer of the Pabst Corporation, Milwaukee, Wis.

William B. Barnes, who was assistant in the experimental laboratory of the Cadillac Motor Car Co., Detroit, has severed his connection with that organization and accepted a position as assistant to the chief engineer of the Wheeler-Schebler Carbureter Co., Indianapolis.

R. E. Benner has become associated with George C. Goethals, 40 Wall Street, New York City, as engineer. He was formerly vice-president of the Hale & Kilburn Corporation, Philadelphia.

O. C. Berry, formerly research engineer of the Hupp Motor Car Co., Detroit, has become chief engineer of the Wheeler-Schebler Carburetor Co., Indianapolis.

Wallace B. Blood has been appointed director of sales and advertising of the Ray Battery Co., Ypsilanti, Mich. He will remain with the Campbell, Blood & Trump Co. of Detroit, of which organization he was vice-president, in an advisory capacity.

George C. Brainard has been elected vice-president of the Hydraulic Steel Co., Cleveland, which office he will hold in connection with that of general manager of the company.

George T. Briggs, who until recently was connected with the automotive department of the Sinclair Refining Co., Chicago, has been appointed general manager of the Motorcycle and Allied Trades Association, with headquarters at 326 West Madison Street, that city.

C. S. Bristow has been made manager of the Bristow Engineering Co., Portland, Ore. He was previously an engineer for the J. I. Case Plow Works Co., Racine, Wis.

Porter A. Buck, formerly assistant engineer for the Power Truck & Tractor Co., Detroit, has accepted a position as chief engineer for the Parcel Industries, Alpena, Mich.

Morris C. Burnside, until recently factory manager for the Anderson Forge & Machine Co., Detroit, has been appointed general manager of the National Engineering Products Co., Detroit and Dallas, Tex.

E. J. Butler has accepted a position with the Eaton Axle Co., Cleveland. He was formerly assistant engineer for the Freeman Motor Co., also of that city.

Robert H. Campbell is now associated with the Farmers Mfg. Co., 105 Scarritt Building, Kansas City, Mo., as vice-president, having resigned as vice-president of the Comet Automobile Co., Decatur, Ill. The Farmers company has taken over the interests of the Coleman Tractor Co., formerly of Kansas City, and expects to resume the production of the Coleman tractor in the near future.

H. I. Crow and F. Leroy Hill have organized the Motive Products Co., 604 Mission Street, San Francisco. Mr. Crow was formerly chief engineer for the Fageol Motors Co. of Ohio, Cleveland.

(*Continued on page 4*)

DIXON'S No. 677 Gear Lubricant

We have called attention to the fact that a gear box lubricant, to do effectively the work for which it is intended, must show minimum power losses in both hot and cold weather.

Tests conducted in our Mechanical Laboratory prove that *at freezing temperature the average gear lubricant will consume at least three times as much power as will Dixon's No. 677.* The average gear lubricant at freezing temperature stiffens to such an extent that the shifting of gears becomes quite a difficult matter. With Dixon's No. 677, however, gear shifting is accomplished as easily as in midsummer.

On a hot summer day the average gear lubricant becomes limpid and leaks through the packings, while Dixon's No. 677 retains its original plastic condition.

The ability of Dixon's No. 677 to withstand extremes of heat and cold results not only in an actual reduction of the power-loss in gear boxes, but also eliminates added strains to which all working parts of a car are subjected when the lubricant is either too hard or too fluid.

JOSEPH DIXON CRUCIBLE CO., Jersey City, N. J.

Makers of Quality Lubricants—Established 1827

For Spur and Bevel Gears
Use DIXON'S No. 677
GEAR LUBRICANT

For Worm Drives
Use DIXON'S No. 675
GEAR OIL

SAVE FUEL

SAVE OIL

BESSEMER MOTOR COMPANY

515 N. Nineteenth Street. Phone 51

Automobiles, Tires, Storage Batteries and Repairs

Michelin Tires and Tubes

Bessemer, Ala.,

Sept. 9, 1920.

The Ever-Tyte Piston Ring Co.,
St. Louis, Mo.

Gentlemen:

We are convinced that Ever-Tyte Piston Rings are the very best piston rings on the market.

We worked with an Oldsmobile at different times for two years trying all the so-called leak-proof piston rings without stopping the oil-pumping and finally used The Ever-Tytes as the last resort. The oil-pumping stopped and the machine is giving the best of satisfaction.

We tried three different makes of so-called leak proof rings in a Scripps-Booth car. Ever-Tyte Piston Rings again solved our problem and we are boosters for your product.

With best wishes for your continued success, we are,

Very truly yours,

BESSEMER MOTOR COMPANY.

per ..... Mgr.

ZELNICKER *Ever-Tytes* are working such wonders daily because of their three piece, interlocked, flexible construction. They hug the cylinder walls tightly, even though slightly out of round. They make reboring of worn cylinders unnecessary.

TRY THEM AT OUR RISK

EVIDENCE BOOKLET SENT ON REQUEST

EVER-TYTE PISTON RING DIVISION

WALTER A. ZELNICKER SUPPLY COMPANY

1600 Kingsland Ave. (Wellston) ST. LOUIS

PERSONAL NOTES OF THE MEMBERS

Continued

H. D. Dabney has severed his connection with the National Association of Motor Truck Sales Managers, Detroit, where he held the position of executive secretary. His future plans have not been announced as yet.

L. R. Davis has become associated with the United States Rubber Co., New York City. He was formerly development engineer for the Revere Rubber Co., Providence, R. I.

C. E. Dickey has resigned as general manager of the Hammond Steel Co., Syracuse, N. Y., and will devote his entire time in the future to the Dickey Steel Co., 233 Broadway, New York City, of which he is president.

I. C. Dickover, formerly engaged in compiling repair parts catalogs for the Kleiber Motor Truck Co., San Francisco, has opened a catalog service at 288 Ninth Street, in that city.

Arthur Dugrey has resigned as superintendent of the carbureter plant of the Ford Motor Co., Detroit. He has not announced his future plans as yet.

Charles A. Erickson has resigned as general manager of the Standard Radiator Co., Springville, N. Y., and has accepted a similar position with the Sterling Radiator Co., Cleveland.

P. J. Eubanks after serving as chief engineer and manager of the Aero Products Co., Cleveland, for two years has resigned. In the future he will devote his entire time to the duties of chief engineer of Rush & Eubanks, a firm of consulting engineers with offices at 806 Engineers' Building, that city.

R. J. Fitness has resigned as consulting engineer and manager of the Detroit office of the Intercolonial Export Agencies, Montreal, Canada, and has accepted a position as assistant chief engineer for the Handley-Knight Co., Kalamazoo, Mich.

Clarence M. Foss has severed his connection with the Willys Corporation, Elizabeth, N. J., where he was service manager, and has become sales engineer for the Walker M. Levett Co., 417 East 23rd Street, New York City.

R. G. Garretson, formerly engineer for the Clark Tructractor Co., Buchanan, Mich., has accepted a position as chief engineer for the Bryan Harvester Co., Peru, Ind.

R. C. Greiner, until recently chief engineer for the U. S. Tractor & Machinery Co., Menasha, Wis., is now engaged in the practice of mechanical engineering at Minneapolis, Minn.

Morris A. Hall, formerly secretary and treasurer of the Gallon-Hall Corporation, and editor of *Automotive Engineering*, New York City, has been elected president of the International Cultivator Corporation, successor to the Termaat-Monahan Mfg. Co., Oshkosh, Wis.

O. D. Heavenrich has accepted a position as engineer for the Apex Motor Corporation, Ypsilanti, Mich.

Joseph Husson, formerly editor of *Commercial Vehicle*, 239 West 39th Street, New York City, has been appointed general sales and advertising manager for the Northway Motors Corporation, 1 Beacon Street, Boston.

Harry E. Jenkins has been appointed sales agent of the U. S. Cartridge Co., Lowell, Mass. He was formerly sales manager and engineer for the Universal Products Co., Detroit.

S. S. Jenkins, who was formerly Detroit district manager of the Bijur Motor Appliance Co., Hoboken, N. J., has been appointed general sales manager with offices at the factory.

Carl E. Johnson, who was previously a designer for the Standard Sanitary Mfg. Co., Louisville, Ky., has become associated with the Delco Co., Dayton, Ohio, in the same capacity.

R. P. Johnson, vice-president and general manager of the Warner Gear Co., Muncie, Ind., was elected first vice-president of the American Gear Manufacturers Association at its fifth annual convention recently held in Cincinnati.

(*Concluded on page* 6)

What Was the Motive of Your West Baden Meeting?

In the five days from May 24 to May 28 over six hundred of the leading automotive engineers of America—all of them S. A. E. members—met in professional and recreational conclave at the West Baden Springs Hotel, West Baden, Indiana.

What was the motive behind this meeting?

It is true that aviation, farm transportation problems and pure engineering topics were analyzed and discussed. But weren't the important papers of your meeting most concerned with the individual motorist—the man who owns and drives his own car?

For, after all, it is the motorist who has made the automotive industry what it is today. Trucks, tractors and aeroplanes we will have in increasingly large numbers, but the very foundation of automotive endeavor is the passenger car itself.

MoToR, the National Magazine of Motoring, fully appreciates the efforts of you engineers to build better motor cars, and this magazine closely follows your footsteps by aiming to teach people how to make better use of them, both from a utility and mechanical standpoint.

We believe that the automotive engineer who reads MoToR regularly will be just a little more efficient because this magazine portrays so faithfully the ideals and ambitions of the man who ultimately receives greatest benefits from the great work you are doing—the individual motorist.

MOTOR

119 West 40th Street **New York, N. Y.**

Where Power Meets Weight

Whir!

The motor of the big truck gathers its full strength for the getaway.

In goes the clutch, and the full power of sixty horse meets the dead weight of many tons —at the exact point where the teeth of two gears meet and mesh, *in the transmission.*

The great carrier fairly leaps into motion and is off again on its day's work.

And the gears? Such work has been little more than play for them—if they are Covert-built.

For Covert gears, so thousands of truck, tractor and passenger car owners will tell you, are proof against every strain that use can impose upon them.

See to it that Covert Gears—the exclusive equipment of Covert Transmissions—are parts of your next automotive investment.

COVERT TRANSMISSIONS

COVERT GEAR COMPANY, INC.

Sales, Engineering and Factory: Lockport, N. Y.
Export Offices: 100 Broad Street, New York City

PERSONAL NOTES OF THE MEMBERS

Concluded

W. A. Jordan has been elected president of Jordan & Co., 305 Broadway, New York City. He was formerly vice-president of the United Motors Service, Inc., Detroit.

Charles C. Kavanaugh has opened a garage at 6 Dugan Street, Sumter S. C. He was formerly service manager for the Jennings-Burkett Motor Co., also of that city.

Crosby King, formerly layout man and designer for the Superior Truck Co., Atlanta, Ga., has joined the engineering department of the Vim Motor Truck Co., Philadelphia, Pa., in a similar capacity.

N. L. Lieberman, general manager of the New Jersey Brass Foundry, Bayonne, N. J., has become associated with J. P. Davies & Co., 1819 Broadway, New York City, specializing in the development, manufacture and sale of automotive equipment.

William E. Metzger, who was formerly vice-president of the Columbia Motors Co., Detroit, has been elected president of the Wills Sainte Claire Co. of Michigan with headquarters at Woodward Avenue and Grand Boulevard, Detroit.

D. Bruce Morgan has not resigned as consulting engineer of the Paquit Ignition Corporation as stated in the May issue of THE JOURNAL. He is engaged in consulting engineering work for various companies including the Paquit corporation and is located at 1819 Broadway, New York City.

Frederick P. Nehrbas has been appointed works manager of the Weidely Motors Co. of Indianapolis. He was until recently a vice-president and general manager of the Premier Motor Corporation, also of that city.

Nelson B. Nelson, formerly superintendent and chief engineer for the Kardell Tractor & Truck Co., St. Louis, and for the past 12 years connected with tractor engineering, has become associated with the New Departure Mfg. Co., Bristol, Conn., and will have charge of engineering at its Chicago office.

Robert B. Porter has severed his connection with the American & British Mfg. Corporation, Bridgeport, Conn., where he was motor-car engineer, and has joined the sales force of the Sherwood Automobile Corporation, 1129 Atlantic Avenue, Brooklyn, N. Y.

L. F. Seaton has been appointed efficiency and purchasing engineer for the University of Nebraska, Lincoln, Neb. He was formerly chief engineer of the Patriot Motors Co., Havelock, Neb.

S. Ward Seeley has resigned as service and publicity manager of the General Motors Acceptance Corporation, 120 West 42nd Street, New York City. No announcement regarding his plans for the future has been made.

J. C. Slager has accepted a position with the International Time Recording Co., Endicott, N. Y. He was formerly chief designer of the Recording & Computing Machines Co., Dayton, Ohio.

Herbert C. Snow has resigned as chief engineer of the Winton Co., Cleveland, Ohio, to accept a similar position with the R. H. Long Co., Framingham, Mass.

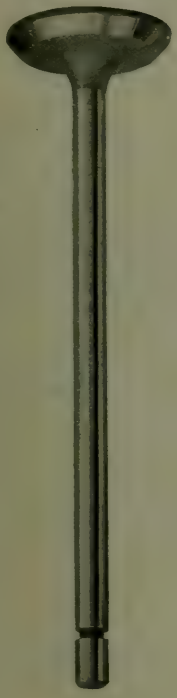
Milton G. Sohn holds the position of civil enginer in the City of Stockton, Cal. He was previously plant engineer for the Redwood Manufacturers Co., Pittsburg, Cal.

John Springer, vice-president and engineer for the Dickinson Cord Tire Corporation, New York City, has resigned and is now located at Farmingdale, N. J.

G. A. Ungar, formerly vice-president of the Engineering & Commerce Corporation, New York City, has been selected by the American Bronze Corporation, Berwyn, Pa., to take charge of its newly established engineering bureau. This bureau will, it is planned, devote its time to a full study of plain bearings, including the collection of authentic data and the conduct of original research work regarding the design, installation, lubrication and maintenance of this type of bearing.

The Steel Products Company

Engineering and Manufacturing Service



Investigation by men who are daily observing the operation of valves, tappets, king bolts, spring bolts, and drag links under various conditions often results in the suggestion of a proper material for a specific purpose—and is based on the knowledge of results actually obtained in cases where similar problems have been presented and solved.

Possibly investigation indicates a condition which has previously been met by change of design or heat treatment.

In other words, the information obtained by our engineers in solving the many problems presented to them may be so applied through proper recommendations as to save time and expense which would be lost if our customers did not take advantage of the knowledge and data accumulated through years of experience in production of parts which have proven satisfactory.

The Steel Products Co.

MAIN PLANT
Cleveland
VALVES
TAPPETS
SPRING, KING AND
TIE ROD BOLTS

MICHIGAN PLANT
Detroit
DRAG LINKS
ROD ASSEMBLIES
STARTING CRANKS
ETC.

BOLT and SCREW PLANT
Cleveland
CHASSIS BOLTS
SPECIAL BOLTS
CAP SCREWS
ETC.

ATWATER KENT

Ignition, Starting and Lighting

Atwater Kent equipment is manufactured to the highest standards of accuracy and precision and truly reflects the personality and ideals of the founder of this business—to make and market a product as good as material, experience and the most exacting workmanship can make it.

Atwater Kent Starting and Lighting is standard equipment on the New Packard Single Six.

GENERATOR

STARTER

An able engineering corps at your service

ATWATER KENT MFG. COMPANY *Philadelphia*

To make your shop produce more at less cost—

with heat-defying wear-resisting Stellite Tools

Fully explained with complete illustrations, charts and detailed instructions.

Compiled in text-book form for the first time. Note the convenient pocket size.

Complimentary copies mailed on request.

Write for yours now.

HAYNES STELLITE COMPANY
Carbide and Carbon Building
30 East 42d Street
New York, N. Y.

Newly developed Stellite Practice—
Assures Large Savings and 25 to 150 Per Cent Increases in Production!

First Time in Print

Get these two new books!

EATON

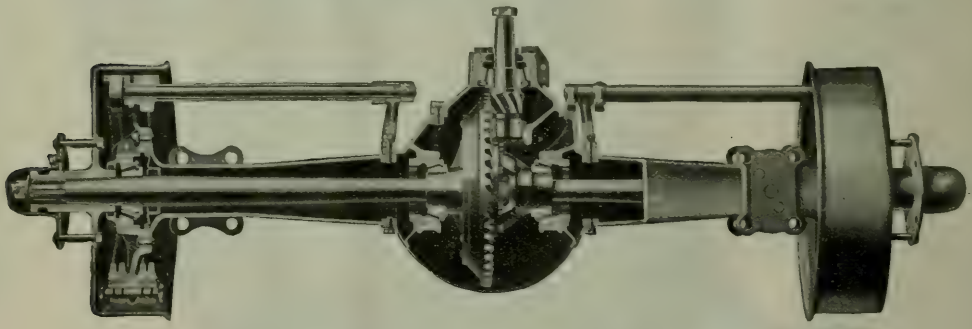
TRANSPORTATION TODAY DEMANDS of its servants greater efficiency and economy, and it is only logical that the high-speed one-ton truck should be widely favored for the despatch of merchandise and farm products.

The swift hauling of a full one-ton load calls for an axle especially planned to deliver high engine torque, an axle made strong enough to stand smashing impact strains and light enough to give a minimum unsprung weight, and one having a reliable braking action.

Such is the Eaton One-Ton Bevel Gear Axle.

Serving under certain of America's finest high-speed one-ton trucks, this staunchly built Eaton product, with its durable drive and large brake drums, is giving an advanced order of axle performance.

On request, detailed drawings and complete specifications of this Eaton Model 1000 and its companion front axle will be placed in the hands of interested truck manufacturers or engineers.



THE EATON AXLE COMPANY, CLEVELAND, OHIO

DIVISION OF THE STANDARD PARTS COMPANY

OTHER DIVISIONS ARE: THE PERFECTION SPRING COMPANY, THE BOCK BEARING COMPANY, THE STANDARD WELDING COMPANY

AXLES

The buyer's market is here. It means intensive competition. A device that insures instant starting throughout the year—the greatest need of the automobile today—will be a vital factor in overcoming both competition and sales resistance.

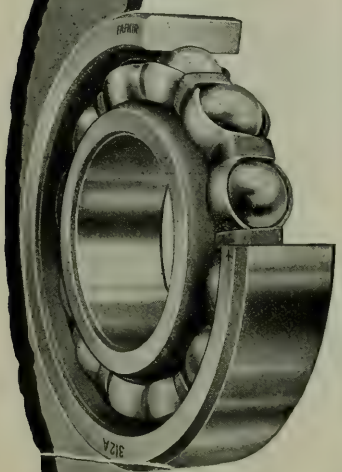
Master
ELECTRICAL PRIMER

Is a perfect starting device that has demonstrated its worth for years as standard equipment on quality cars. It insures starting within seven seconds in any weather. It saves time and gasoline. Less current used from battery with Master Electrical Primer than without it. And, too, it prevents flooding of the engine with raw gasoline, thereby eliminating crank case dilution and consequent piston, cylinder and bearing wear.

Master Primer Company
130 E. Larned Street **Detroit, Michigan**

Standard Equipment on Quality Cars

FAFNIR



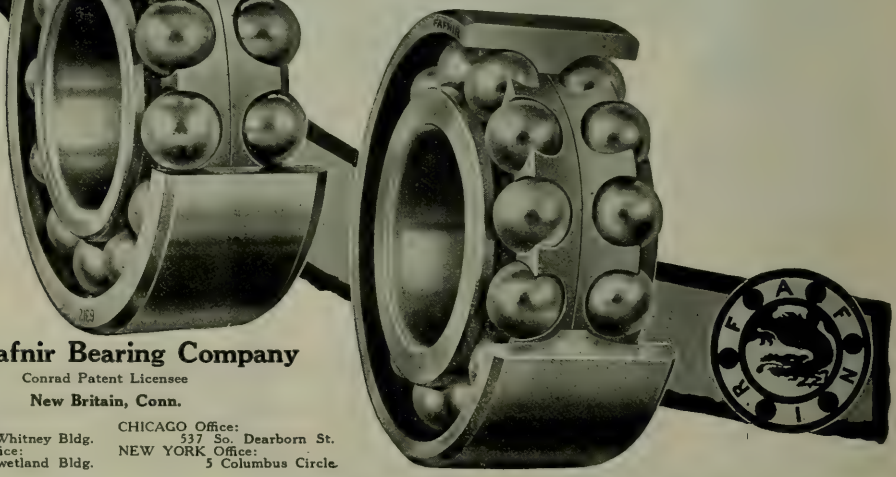
THREE types of **Fafnir Ball Bearings** are shown in the accompanying photographs.

The **single row Fafnir Radial Ball Bearing** is best in most cases involving radial load or radial load plus moderate end thrust load in one or both directions.

The **double row Fafnir Radial Ball Bearing** is advantageous when the details of construction are such as to require a bearing of minimum diameter without a sacrifice of load carrying capacity. For example, a ball bearing of this type would be just the thing to install back of a passenger car bevel gear drive pinion, in any case where the high speed of revolution and design of the surrounding parts of the mechanism require a ball bearing of great load carrying capacity and minimum diameter, and where the end thrust is not too heavy for a **radial** type of bearing.

The **double row Fafnir Radial-Thrust Ball Bearing** is useful for carrying radial load plus heavy end thrust load in one or both directions on a single ball bearing. For instance, a **Fafnir Ball Bearing** of this type is very useful in the case of a worm driven motor truck, for carrying the radial load at one end of the worm and also the extremely heavy worm thrust which is double acting, depending on whether the worm is in forward or reverse drive.

We wish to stress the fact that, in addition to the types illustrated on this page, **Fafnir Ball Bearings** are manufactured in **all** standard types and sizes, **all** of which are produced with the utmost precision from scientifically heat treated high carbon, chrome alloy steel.



The Fafnir Bearing Company

Conrad Patent Licensee

New Britain, Conn.

DETROIT Office:
752 David Whitney Bldg.
CLEVELAND Office:
916-917 Swetland Bldg.
CHICAGO Office:
537 So. Dearborn St.
NEW YORK Office:
5 Columbus Circle

INTERNAL COMBUSTION POWER UNITS BULLETIN No. 3

THE MATERIAL

Successful Power Units require a material that will retain the true shape imparted by careful workmanship and proven design, under wide variations of pressure and temperature.

Grey Iron has been generally accepted as the most practical material for Pistons, Piston Rings and Valves (cast heads with steel stems). There are, however, certain faults in this metal, as usually obtained, which must be eliminated before the manufacturers and users of Internal Combustion Motors will acknowledge this to be the ideal material. These faults are-

"Weakness, Brittleness, Porosity, Elastic and Too Hard, or Soft and Non-elastic, GROWING and WARPING with repeated heatings, Frequent Oxidation and Inconsistencies between the various heats."

Many metalurgists have, for some time, believed that these faults result from the method of making ordinary iron castings, rather than being characteristics of the alloy. The majority of the elements present, other than iron, being in reality impurities remaining from a melting process that is seldom, if ever, refining and generally the direct opposite.

The usual foundry practice in the United States produces, for Internal Combustion Power Units, an iron whose composition averages within the following limits-

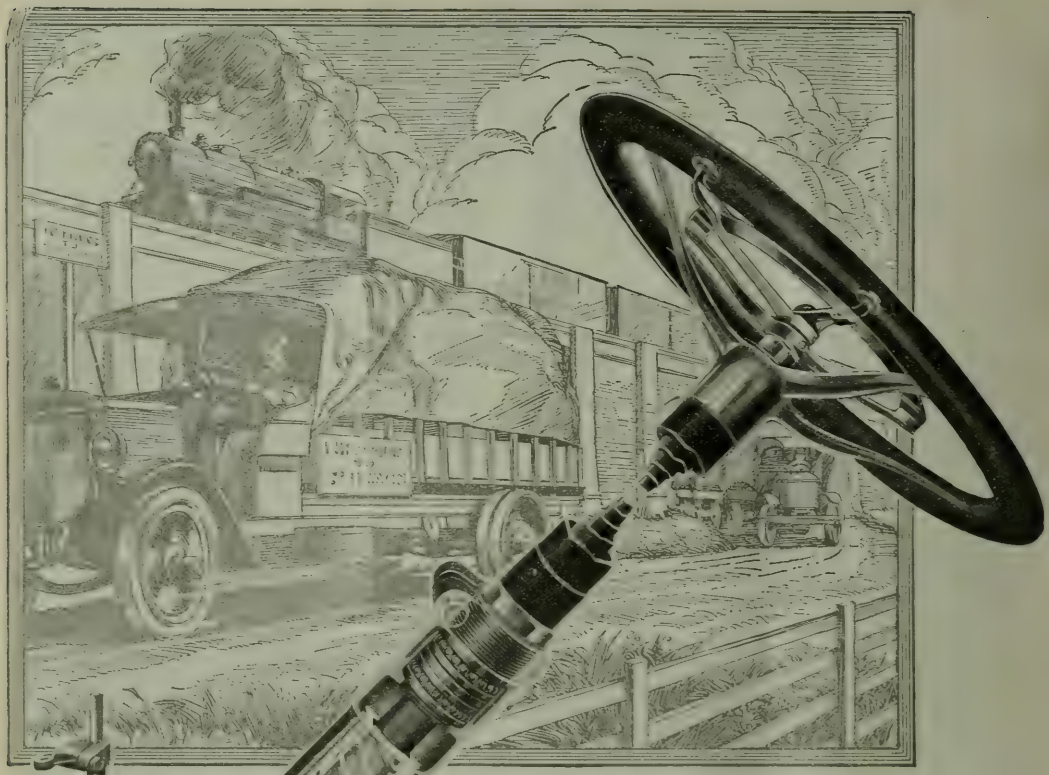
Silicon	1.75 to 2.25%
Sulphur	0.07 to 0.12
Phosphorus	0.60 to 0.85
Manganese	0.50 to 0.75
Combined Carbon	0.50 to 1.00
Graphitic Carbon	2.40 to 3.00
Total Carbon	3.00 to 3.50

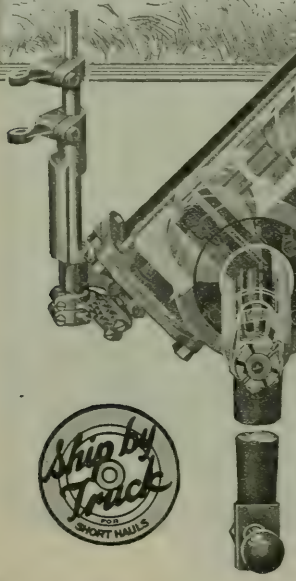
A few foundries have better mixtures, a number work more closely and consistently, but the majority of reputable concerns are in the habit of furnishing grey iron analyzing approximately to these figures.

SEYMOUR LABORATORIED UNITS, INC.

W. E. SEYMOUR, President *"More Than a Manufacturing Corporation"* MILWAUKEE, WIS.

Detroit Sales and Warehouse Office, 1001 Book Building





Ship by Truck FOR SHORT HAULS

Better Transportation
—The Nation's Vital Need

With rail facilities taxed to the breaking point, our biggest problem today is to relieve this strain and help transportation keep pace with industry and agriculture. Unquestionably the solution is the motor truck. Its worth has already been established, and the necessity for its use on a larger scale is becoming more and more apparent every day.

Ross Steering Gears have played an important part in making the motor truck a more efficient and reliable means of transportation. The easy steering, safety and reliability, which are guaranteed by the exclusive screw and nut design, have made Ross Steering Gears standard equipment on 455 different motor truck models from 178 different manufacturers.

Write for any further information desired

ROSS GEAR & TOOL COMPANY
8th and Heath Sts., Lafayette, Ind., U. S. A.

ROSS STEERING GEARS

THE STEERING GEARS THAT PREDOMINATE ON MOTOR TRUCKS

Wisconsin
CONSISTENT

SPECIFICATIONS

A study of the features that have given Wisconsin Motors their prominent place among truck and tractor power units, reveals the designer's great care to produce power plants for service beyond the accepted limits of good service.

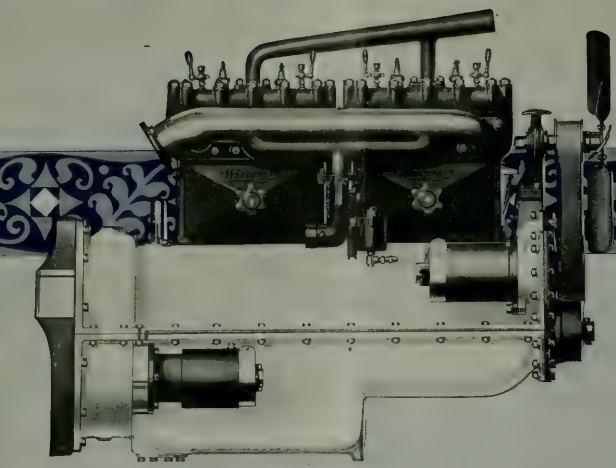
These special features will interest makers of trucks and tractors who wish to incorporate real quality into their product—who build to create reorders for their product—whose reputation is built into every vehicle they sell.

Wisconsin practice is perfected to support the truck and tractor builder in every statement he makes for his product. Our experience and assistance to many of the best known manufacturers has been the means of bringing them a steady flow of business.

Here are the points of Wisconsin construction that can help you in your marketing problems.

Aluminum crank case—Three point suspension—All steel supports—Chrome Nickle Crank Shaft—Force feed Lubrication—All bearings extra large bronze lined with babbitt metal—Tungsten steel exhaust valves—Wide fan gears—Rigid fan belt and drive—Special provision to prevent oil leaks—Combination inlet and exhaust valves—Valve stems and tappets automatically lubricated from crank chamber—Oil tight valve cover plates.

We shall be glad to detail any of these points upon request.



SERVICE

A well known figure in the industry, in addressing a dealer organization told them to "begin every line and sentence of your effort, and end every line with *"service."*

Service is all-important in keeping the truck owner sold. An hour or a day laid up because of inability to secure a necessary part will be remembered when occasion comes to talk about the purchase of another truck.

The Wisconsin Motor Manufacturing Company realizes the penalties for failure to keep a vehicle on the road. Accordingly, undivided attention is given calls for parts or service that the vehicle manufacturer cannot furnish.

This assistance to both the manufacturer and dealer is finding approval with fleet owners and with individuals. It is having its effect where the merits of trucks are discussed, and the good-will established by our efforts is helping sales to a very appreciable extent.

Wisconsin Motors make the truck last—
and one truck sells another.

WISCONSIN MOTOR MFG. CO.
MILWAUKEE, WIS.

Wisconsin
CONSISTENT

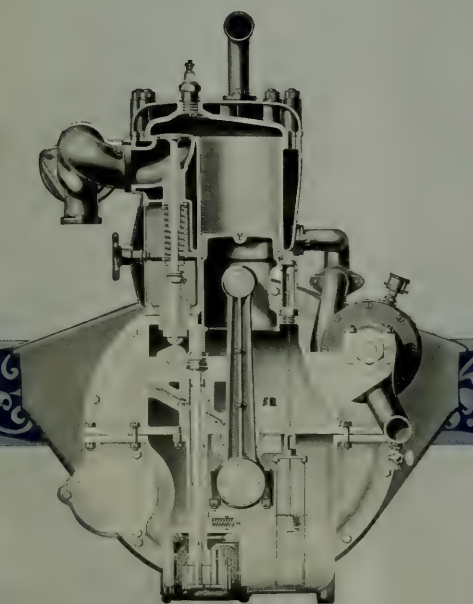
DISTRIBUTORS

T. M. FENNER
21 Park Row, New York City

CHANDLER - HUDSON CO.
Seattle, Washington

WISCONSIN MOTOR PARTS CO.
2354 Cottage Grove Avenue
Chicago, Illinois

EARL P. COOPER COMPANY
1310 South Los Angeles Street
Los Angeles, California



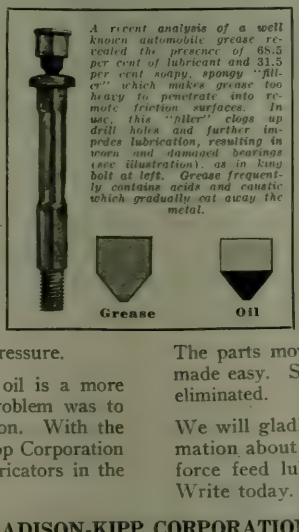
Pumps 1,200 pounds—and more
Convincing proof of the efficiency of Oil-Kipps

When we are asked to prove that Oil-Kipps actually force heavy oil around the bearing surfaces of steering spindles, shackle bolts, spring bolts and other points on the chassis requiring lubrication, we do this:

We attach an Oil-Kipp to a pressure gauge registering, say, 1,500 pounds. Then we pump the plunger and the dial begins to register—the needle passes 500 pounds, 1,000 pounds, 1,200 pounds, and more. It even exceeds the capacity of the gauge.

We do this on your own gauge, or on ours. We ask you to do it. We invite you to test any other device, using either grease or oil, in the same way—and we'll venture the prediction right now that Oil-Kipps will register more than twice the pressure.

Many engineers have long believed that oil is a more efficient lubricant than grease, but the problem was to find a way to use it for chassis lubrication. With the invention of Oil-Kipps by the Madison-Kipp Corporation—the largest manufacturers of motor lubricators in the world—the way has been found.


A recent analysis of a well known automobile grease revealed the presence of 68.5 per cent of lubricant and 31.5 per cent soapy, spongy "filler" which makes grease too heavy to penetrate into remote friction surfaces. In use, this "filler" clogs up drill holes and further impedes lubrication, resulting in worn and damaged bearings (see illustration), as in king bolt at left. Grease frequently contains acids and caustic which gradually eat away the metal.
Grease
Oil

What are Oil-Kipps?

Oil-Kipps are small repeating oil-pumps, accumulating a pressure of more than 1,200 pounds per square inch, which force heavy oil over the bearing surfaces where grease cannot penetrate. They are easy to operate—just pump the plunger a few times and the oil is forced all the way around the bearing. They are easy to fill—one filling provides twenty or more shots, enough for a month or longer.

With Oil-Kipps on the steering gear, it takes but a few seconds to pump an abundant supply of pure, fresh oil to the bearing surfaces where wear is heaviest.

The parts move freely, one upon another. Steering is made easy. Squeaks and rattles and excessive wear are eliminated.

We will gladly supply blue prints and detailed information about Oil-Kipps, also about the new Oil-Kipp force feed lubrication of the clutch release bearing. Write today.

MADISON-KIPP CORPORATION,
Madison, Wisconsin

Vertical Oil-Kipps for steering knuckles and other vertical positions

Oil-Kipps

SILENCE THE CHASSIS

Horizontal Oil-Kipps for spring bolts and other horizontal bearings

The technical knowledge that comes to you from SKF engineers is

as it is the sum of the data gathered by SKF organizations in all industrial countries.

This fund of engineering information we bring to the fabrication of all products bearing the mark SKF and the operation of those industries which we are requested to supervise. In order that complete reliance may be placed in the endorsement expressed by the mark SKF it is necessary not alone that we control and supervise each step in the manufacture of a product but also its final installation.

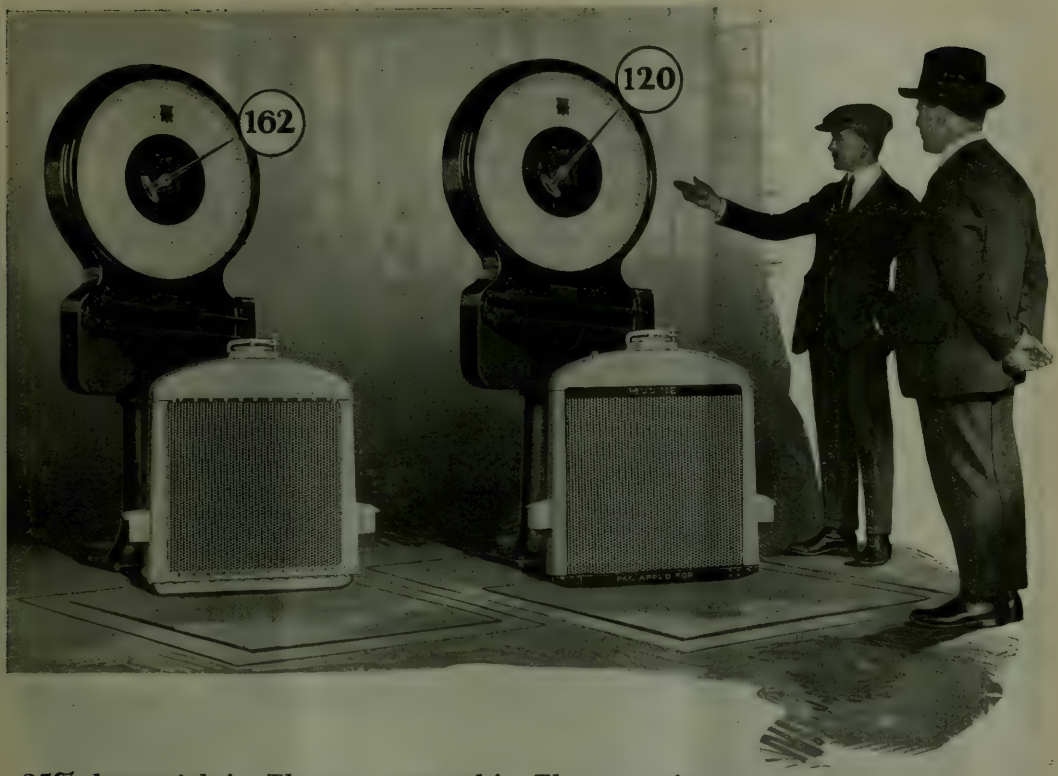
Because every effort is made to assure the most satisfactory use of products marked SKF we welcome requests for information concerning their proper application and maintenance.

Automotive manufacturers should feel that this technical knowledge is always available. You are urged to use it freely without any sense of obligation.

SKF Industries, Inc.
165 Broadway, New York City

Supervising at the request of the stockholders.
The Hess-Bright Manufacturing Co.
The Skayef Ball Bearing Co.
Atlas Ball Co.
Hubbard Machine Co.
SKF Research Laboratory

620



25% less weight! The same strength! The same rigidity! The same cooling!—all at less cost! This is what you get in Modine Suspension Core Construction!

The heavy, cast iron bottom tank is entirely dispensed with. Two small gaskets and four cap screws replace two large gaskets, four fastening bars and a mass of nuts, bolts and lock washers. Material, machining and assembly costs—all have been cut to a minimum in this new Modine method of constructing heavy duty radiators.

Modine Suspension Core Construction (Pat. applied for) can be obtained only with either a Modine Spirex or a Modine Tubular core—a combination which insures both manufacturer and purchaser the greatest possible cooling capacity per unit of total radiator weight.

The famous Spirex spiral provides maximum cooling.. It maintains the colder air against the hot sides of the water channels. This assures the highest possible rate of heat transmission. Every cubic inch of air leaves the core saturated with heat. The Modine Spirex core can be furnished in any type of construction.

Modine Manufacturing Company

210 Sattley Bldg. **Racine, Wis.**

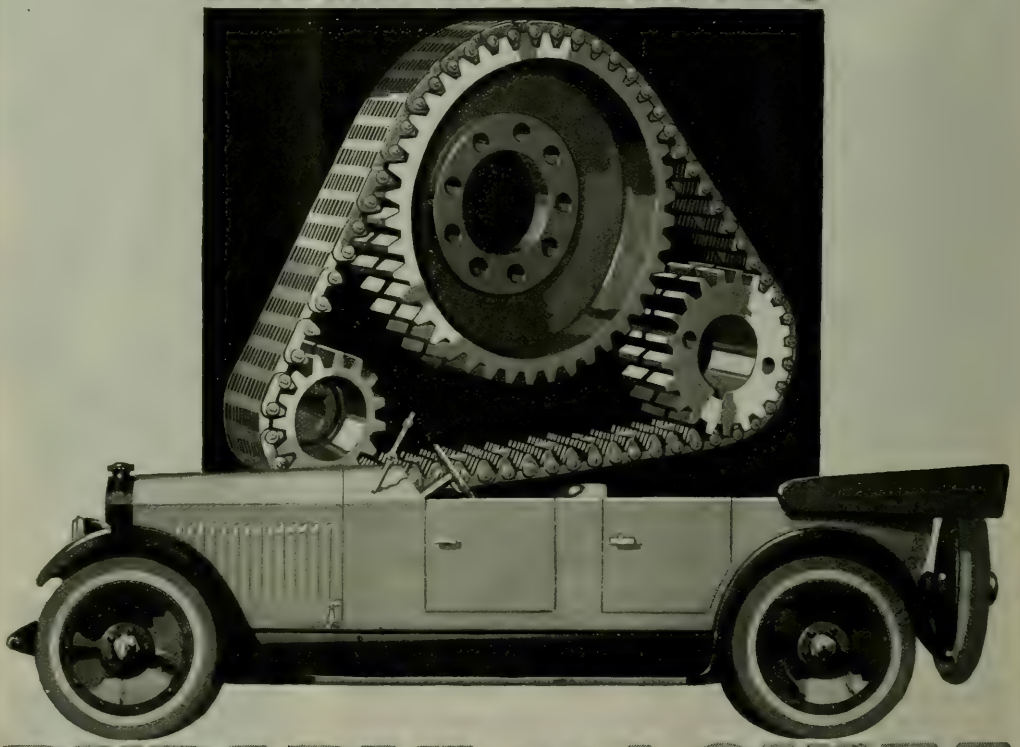
F. Somers Peterson
Pacific Coast Representative

San Francisco *California*

SPIREX MODINE RADIATORS TUBULAR MODINE RADIATORS

MORSE

FRONT END DRIVES



DURABLE and QUIET

Basing our predictions of the future on the constant healthy growth of the past in which our oldest customers are our present customers, we believe that the next cycle of changes in the automobile engine design will reveal the Morse Front End Drive used far in excess of any other known form of timing drive.

Write for latest list of factory equipped cars.

MORSE CHAIN COMPANY

MAIN OFFICE AND WORKS

ITHACA N. Y.

SALES AND ENGINEERING OFFICE

COR. EIGHTH & ABBOTT STS. DETROIT, MICHIGAN

Jefferson DROP FORGED Steel Wheels for Passenger Cars

Jefferson Drop Forged Steel Wheels are the result of co-ordinating two positively new principles of wheel making—Drop forging and Unit construction, producing

ONE PIECE

rugged, elastic steel wheels of greatest strength. Hub, brake drum, spokes and felloe are drop forged integral—no bolts, nuts, rivets, welds or joined sections.

LIGHTER THAN WOOD

wire, or disc wheels of standard construction—unaffected by extreme heat, cold, dryness or dampness. They are

INDESTRUCTIBLE

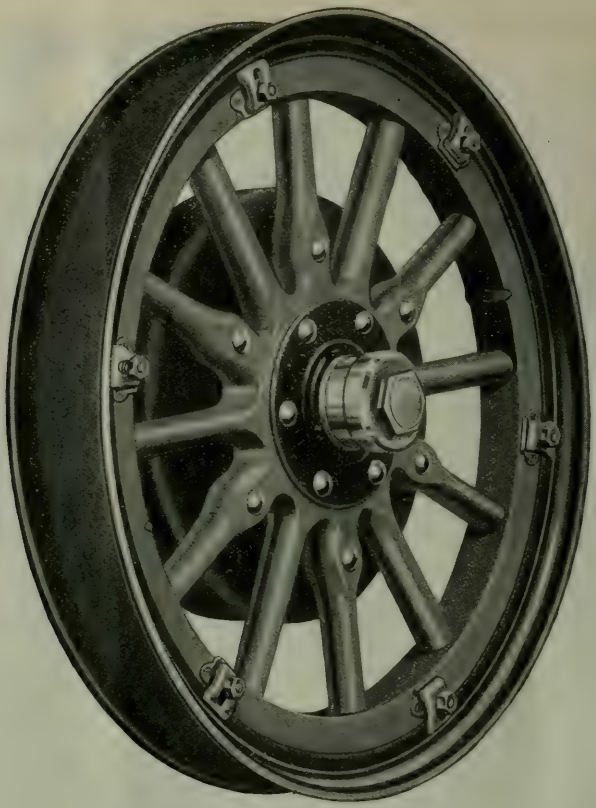
and are guaranteed for the life of the car on which they are used—a positive assurance of safety, economy, and freedom from wheel annoyances. They are made by the same process as crank shafts, axles, steering knuckles, transmission gears and other motor car parts enduring constant pounding strains and stresses.

*"The hand of force * * * can not disjoin them"*

Th Jefferson

RUSSELL A. ALGER, *President*
FREDERICK M. ALGER, *Vice-Pres.*
CHARLES E. WADE, *Vice Pres. & Gen. Mgr.*
F. ARCHER HINCHMAN, *Sec'y & Treas.*

THE JEFFERSON FORGE PRODUCTS CO. DETROIT, (*Established 15 Years*)



EVERY piece of wood in this wheel is the highest grade hickory, carefully selected, cut in our own forests, thoroughly air seasoned —and then finally dried in the latest and most scientific type of dry kilns.

Right here is the foundation of the quality, character, and uniformity of each and every one of the four million wood wheels produced annually by the Motor Wheel Corporation.

MOTOR WHEEL CORPORATION - LANSING, MICH.

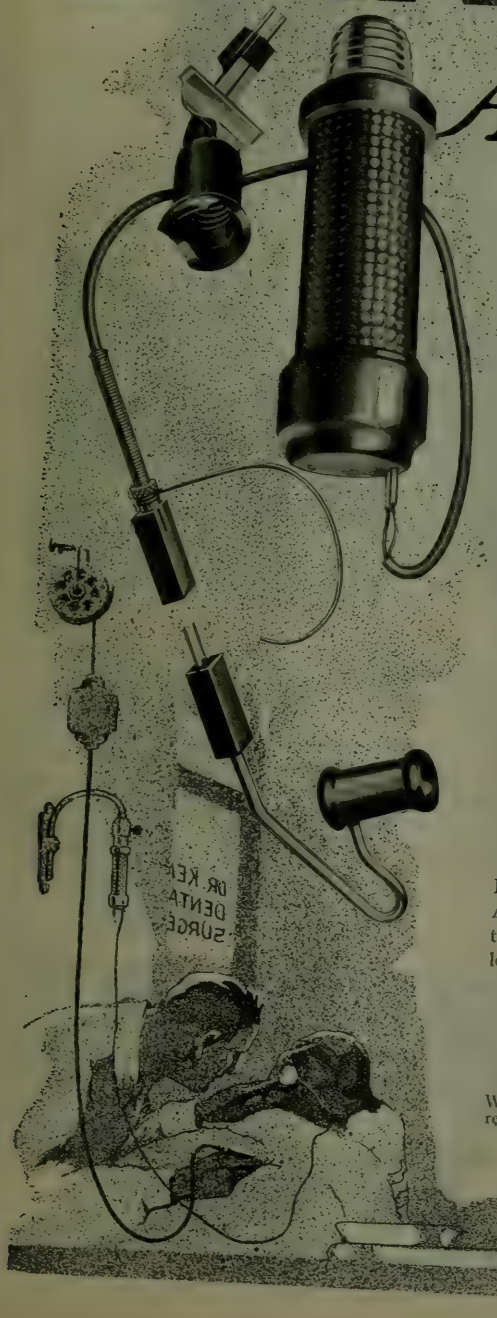
Motor Vehicle Wheels Complete — Metal Stampings — Steel Products

Makers of Gier Tuarc Steel Wheels

Motor Wheel PRODUCTS

BAKELITE

REG. U. S. PAT. OFF.



A dental lamp MOULDED

Dentistry has made strides since the Egyptians plugged their teeth with copper, lead, or gold. Step by step the science has advanced, and for every new improvement a material has been found to make its application possible.

A lamp to provide proper illumination within the patient's mouth called for a material possessing an unusual combination of remarkable qualities. The deleterious action of saliva is well known: any lamp for the purpose must be acid and alkali proof. The sensitive tissues had to be protected from even the low heat generated by a small bulb; and this called for a perfect non-conductor. The absorption of moisture and germs would have made such a lamp useless: a high degree of denseness was essential. It is necessary that dental apparatus be frequently sterilized by boiling; a soluble substance would have made this impossible. And the material chosen had to be a non-conductor of electricity, to make practicable the manufacture of such a lamp.

Bakelite, moulded, has qualified in every respect. It resists acids and alkalis; it is a non-conductor of both heat and electricity; it is infusible, insoluble, and chemically inert. It may be moulded in practically any shape and size, incorporating metal inserts accurately in place. It is of extremely low porosity, has a specific gravity of 1.35, and maintains a high finish under all conditions.

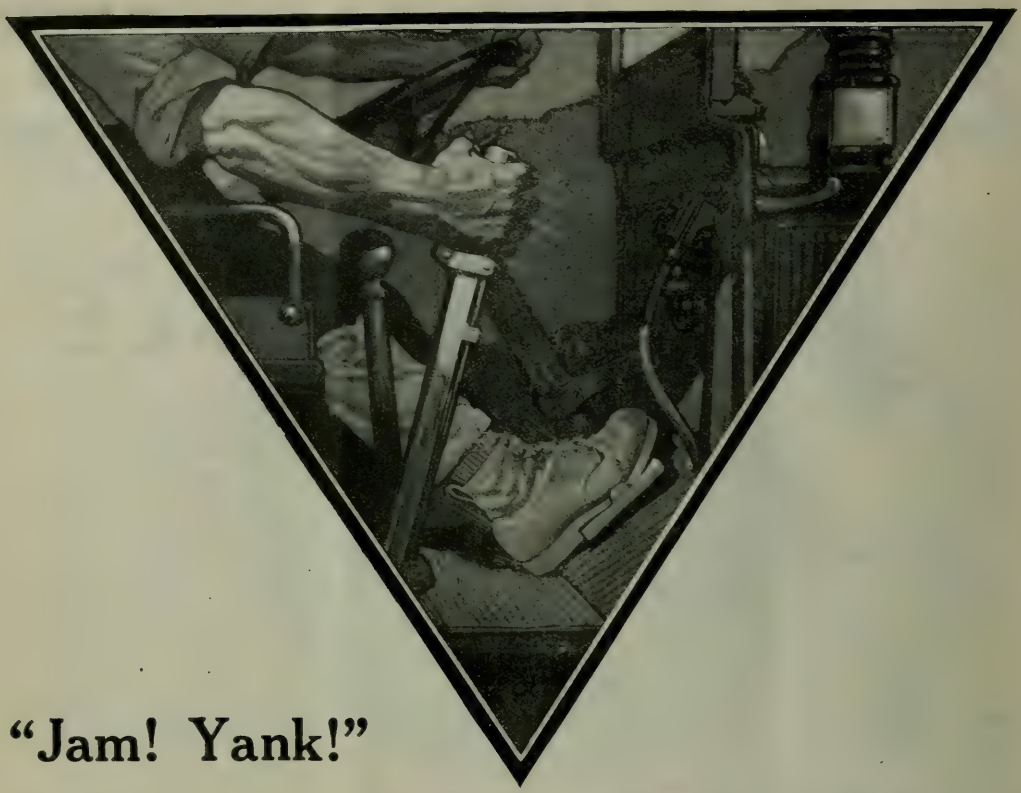
Bakelite has established itself in almost every industry. A phenolic condensation product, it provides manufacturers with a *new raw material*, capable of almost limitless application. Perhaps you could use it.

GENERAL BAKELITE COMPANY

TWO RECTOR STREET, NEW YORK, N. Y.

We welcome inquiries from manufacturers, and maintain a research laboratory for the working out of new applications.

2086-B



"Jam! Yank!"

Out with the clutch—
Down on the service brake—
Back on the emergency with all the force you've got!

* * * * * *

IT takes quick thinking and sound muscle to bring 10 tons of moving load to a stop—and it's no small job for the brakes.

Yet thousands of Timken Brakes are daily meeting the excessive demands of the emergency stop. Their quick, sure action is a safeguard to driver, truck and traffic.

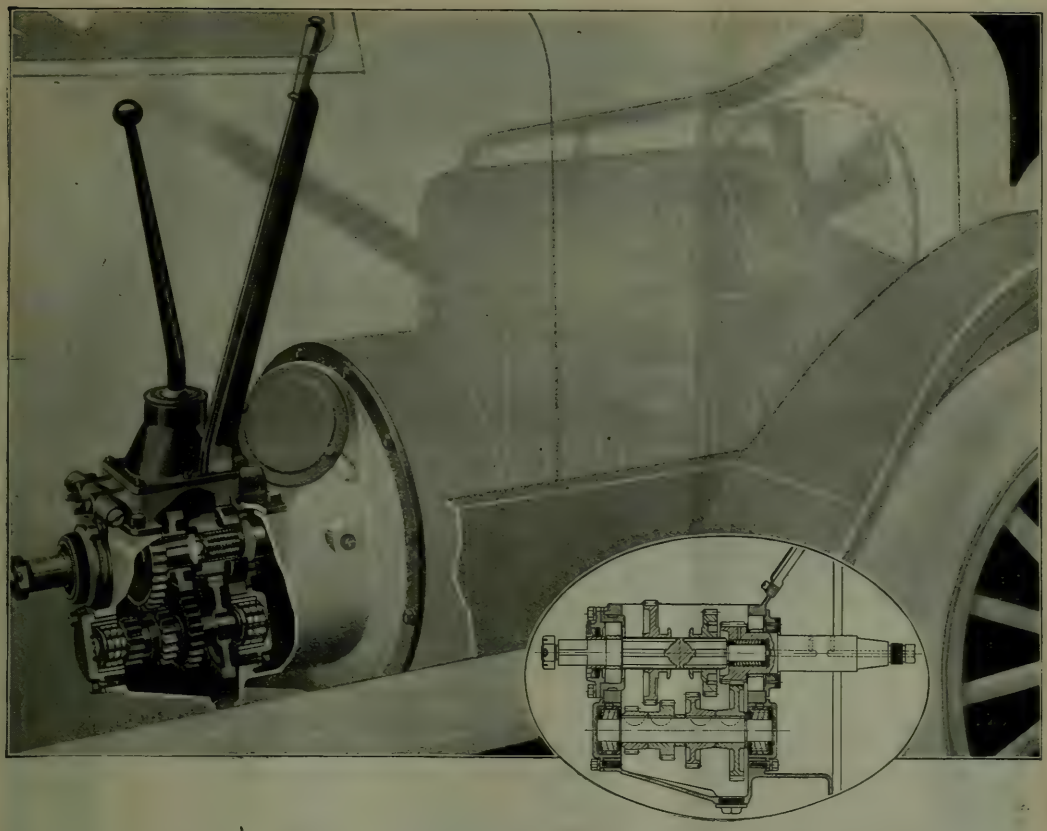
The simple mechanism of the Timken patented Duplex Brake gives the shoes their powerful pressure on the drums. The even distribution of pressure on the full width of the brake drums prevents skewing—no uneven wear.

Timken engineering and manufacturing skill and experience make possible such accurate and sturdy design — such power, ruggedness and reliability—that no demand has ever been made for repair or replacement of Timken Duplex Brake parts.

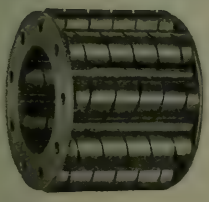
THE TIMKEN-DETROIT AXLE COMPANY · DETROIT, MICHIGAN

TIMKEN AXLES

DTA CO



A Transmission Simplified by Hyatt Roller Bearings



And in Operation

Hyatt Roller Bearings relieve the transmission of all the road shocks and strains—insuring perfect alignment of gears and shafts—thereby minimizing wear and tear.

In addition, they are self-oiling, never need adjustment and survive throughout the life of the vehicle. To have them in your transmission is your assurance of dependable performance.

The compact transmission of this car has Hyatt Roller Bearings on the countershaft ends and on the "spigot" end of the mainshaft, where it pilots into the clutch gear.

The "Spigot" bearing consists of a cage of small rollers. Elimination of races at this point permits holding shaft parts to a minimum diameter. Bearings without inner races are used on the countershaft, thereby doing away with extra parts. End thrust is taken through generous contact surface against plain oil channeled end caps.

This design illustrates the sound manner in which Hyatt Roller Bearings, through their adaptability, simplify construction and enable the manufacturer to build a more satisfactory transmission without adding to the cost of the unit.

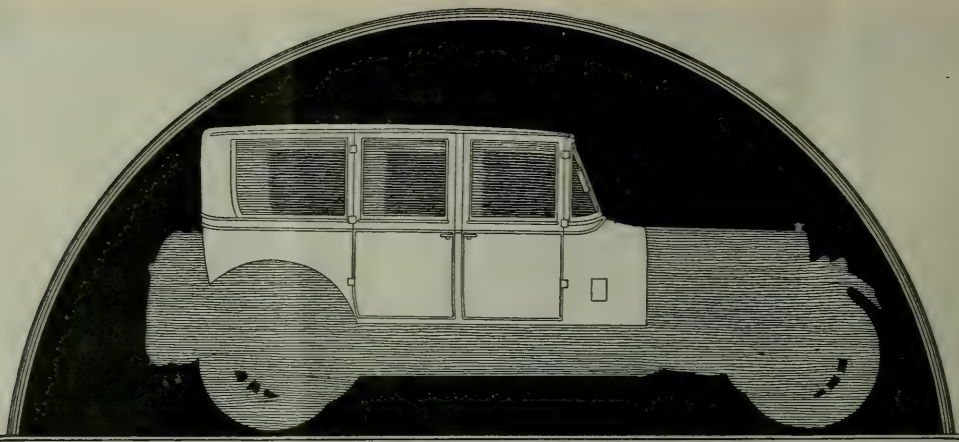
HYATT ROLLER BEARING COMPANY

Motor Bearings Division Detroit, Michigan

Tractor Bearings Division Chicago, Ill.

Industrial Bearings Division New York, N. Y.

HYATT QUIET BEARINGS



An Actual Sales Maker

RAULANG Aluminum Bodies for your new enclosed models *will make traceable sales for you and your dealers.* Raulang Bodies combine every major feature which appeals to car-buyers and puts these sales-making features in *your* cars at a cost to you no greater than you may be paying for inferior coachwork.

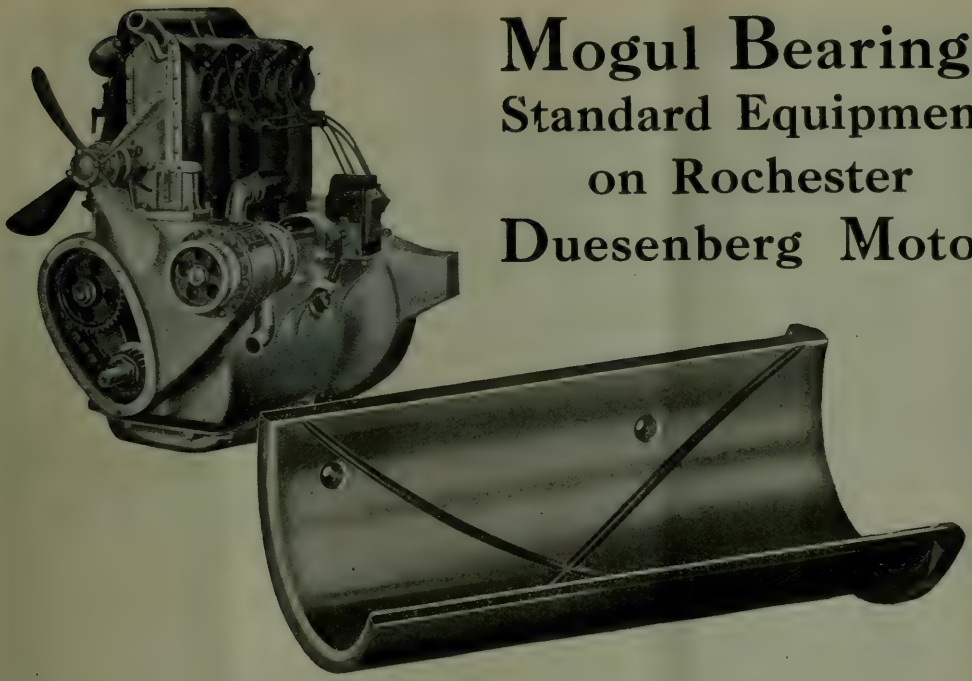
On close competitive sales give your dealers the advantage of the extra attraction of Raulang Bodies.

Raulang Bodies are now available in these models:

REO COUPE
REO SEDAN
LEXINGTON SEDANETTE
RAUCH & LANG BROUGHAM
RAUCH & LANG COACH
STEVENS-DURYEA LIMOUSINE

RAULANG BODY DIVISION
The Baker R & L Co.
CLEVELAND, OHIO. U.S.A.

Raulang
TRADE MARK
AUTOMOBILE BODIES



Mogul Bearings Standard Equipment on Rochester Duesenberg Motor

YOU naturally expect Mogul Bearings on the powerful, sure-working Rochester-Duesenberg motor. The Roamer, the Revere, and the Meteor are powered by this unique and silent engine —which has gained its reputation for dependability through the continuous perfect functioning of every part.

There are definite reasons why Mogul Bearings are standard equipment on the Rochester-Duesenberg and other motors of quality cars. Virgin metals, correct formula, perfect alloys—these, and years of specialized experience in the manufacture of quality bearings are the chief reasons.

And then comes the final reason, the Mogul Trade-Mark—the guarantee of Mogul excellency. Back of it are 14 inspections and a final rigid inspection to detect any imperfection of size, weight, or density. That is why Mogul Bearings meet your specifications to the "one-thousandth part of an inch."

Specify Mogul Bearings

MUZZY-LYON COMPANY DETROIT, MICHIGAN

Mogul

Bearing Alloys *and* Finished Bearings

Increased frame quality is as great an economy as decreased cost

THE new Parish frames of heat-treated Mo-*lyb*-den-um Steel are so much *stronger*, so much *tougher*, so much *lighter* than ordinary steel frames that they represent greater economy in every respect.

For increased quality in an article is as great an expression of economy as decreased cost.

Mo-*lyb*-den-um Steel has been widely adopted in the automotive industry. And we are the first to use it in frame construction. When heat-treated it offers advantages impossible of attainment with any other steel.

Under the extremes of every-day use it develops no permanent "set."

It gives longer life because it has a greater ability to resist shock and fatigue.

It makes possible lighter construction, both in the frame itself and consequently in the other units of the car. This lowers manufacturing costs to you as well as upkeep costs to your customers.

Parish engineers will work with you in designing a Mo-*lyb*-den-um Steel frame for your car, a better method than merely following a specification sheet. Their long experience in the heat treatment of alloy steels *plus* an exhaustive study of Mo-*lyb*-den-um has given them a fund of information freely available.

Write us for particulars

PARISH MANUFACTURING CORPORATION
READING, PA. DETROIT, MICH.

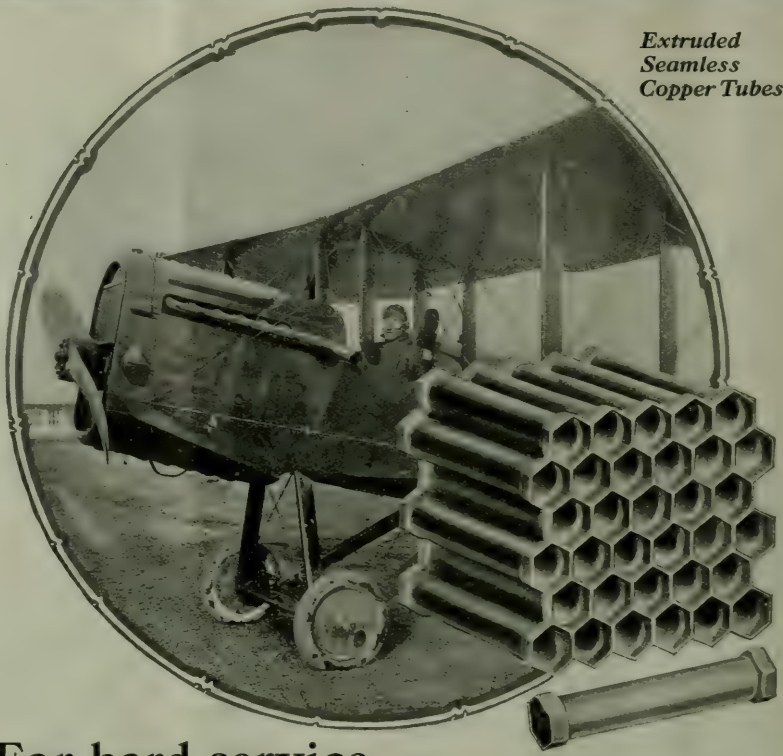
PARISH
MO-LYB-DEN-UM FRAMES

LINK-BELT
SILENT CHAIN DRIVES

FOR MOTOR FRONT ENDS

Link-Belt Silent Chain—a positive yet flexible drive, quiet in its operation, equipped with the Link-Belt tightener that automatically keeps just the right operating tension on the chain at all times.

LINK-BELT COMPANY
INDIANAPOLIS INDIANA



Extruded Seamless Copper Tubes

For hard service— a Cartridge Radiator

It is made of a great many seamless tubes —the picture shows how they are assembled. These tubes can't leak; and they make a radiator that can be guaranteed for the life of a motor car. This is the type of radiator used in all U. S. Army and Postal airplanes.

This construction is adaptable to an almost infinite variety of design; that's why these radiators are so distinctive in appearance. The best European cars have used radiators of this type for many years.

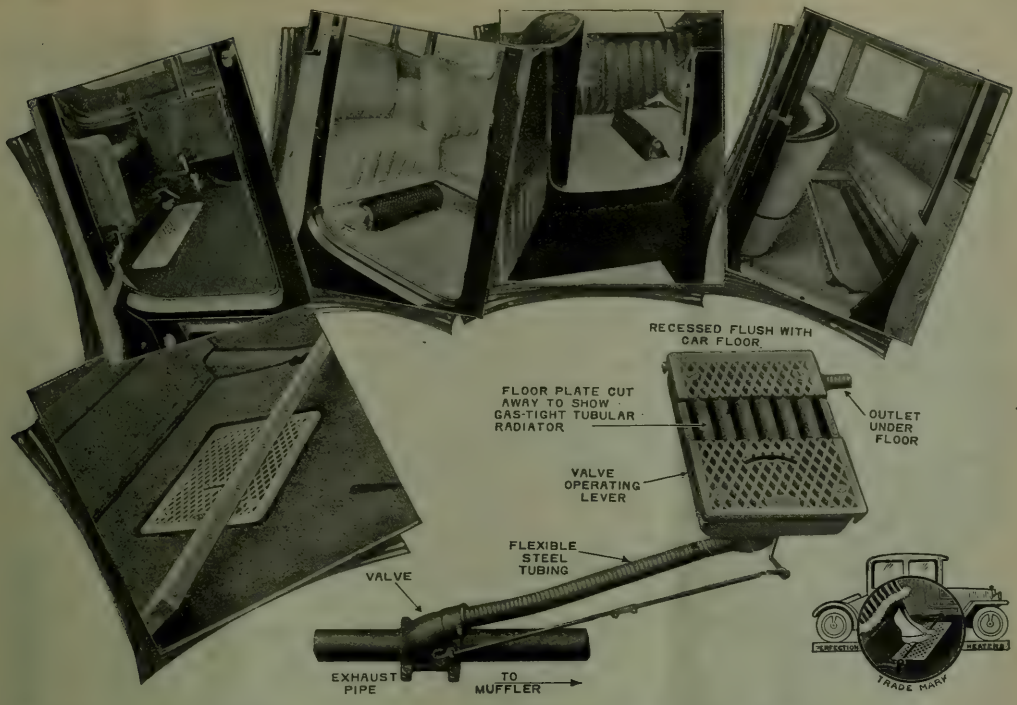
The tubes that go into these radiators are *extruded* from pure copper blanks. They are seamless and uniform. Radiator cores built up from them are strong, rigid, and stay tight. Should an accident damage any of the tubes, they can be replaced easily without taking the radiator down. And these copper tubes are proof against corrosion.

The Ansted Company of New York, makers of radiators for fine cars, use these seamless *extruded* tubes. They think so well of them that they will guarantee radiators made from them for the life of the car.

CARTRIDGE
Seamless Radiator Tubes

Engineers and manufacturers realize the importance of trying every improvement in automotive equipment. This radiator should be an important help in the continual competitive fight against obsolescence. We welcome inquiries; write today.

UNITED STATES CARTRIDGE CO.
Lowell (US) Mass.



Some of the cars using Perfection Motor Car Heaters as Standard Equipment on one or more models:

Allen	National
Case	Northway Motors
Cole Aero-Eight	Corp. (truck
Columbia	cab bodies)
Crow-Elkhart	Oakland
Davis	Oldsmobile
Dixie Flyer	Paige
Dorris	Premier (all
DuPont	models)
Gardner	Re Vere
Grant	R & V Knight
Handley-Knight	Scripps-Booth
Haynes	Sheridan
Holmes	Standard Eight
Hudson	Stutz
King	Stephens Salient
Kissel	Six
Liberty	Templar
Maibohm	Velie
Marmon	Willys-Knight
Mercer	Westcott
Mitchell	Yellow Taxicabs
Moon	of Chicago

PERFECTION MOTOR CAR HEATERS

"Heaters go with most closed cars and SHOULD BE STANDARD EQUIPMENT FOR ALL. There seems to be no excuse for putting them out minus a contrivance of this sort."—From Automobile Topics, Feb. 5, 1921.

When we are permitted to announce new contracts recently closed for Perfection Heaters, there will no longer be any doubt that heaters are an essential feature of motor car equipment.

More different makes and a MUCH LARGER TOTAL NUMBER of cars will be equipped with Perfection Heaters by manufacturers this year than ever before.

If you contemplate any price changes the above facts should be carefully considered before revised prices are announced.

"The Heat Is There—Why Not Use It?"

The Perfection Heater & Mfg. Co.

6554 Carnegie Ave. **Cleveland, Ohio**

Willard Advertising and—

Who Pays for It

Willard believes in advertising.

Of course that advertising must be paid for.

By whom?

If it *increases* the price of the battery, your customer pays for it. If it *decreases* the company's dividends the stockholders pay for it. If it *decreases* the dealer's margin of profit he pays for it.

As a matter of fact none of these things happens. What does take place is this: The advertising creates a substantial foundation of good-will that is reflected in a more even demand for Willard Threaded Rubber Batteries. The greater demand permits manufacture on a scale that introduces manufacturing economies and consequently reduces manufacturing costs. The increased production enables us to build up an efficient sales organization and keep it busy, so that still further economies are possible. The result is a lower price to the *consumer* and a better profit for the *dealer*.

Willard Advertising has to be paid for, but it is paid for by economy of material and time that gives added value, and brings added satisfaction to all concerned.

WILLARD STORAGE BATTERY CO.
Cleveland, Ohio

Willard THREADED RUBBER BATTERY

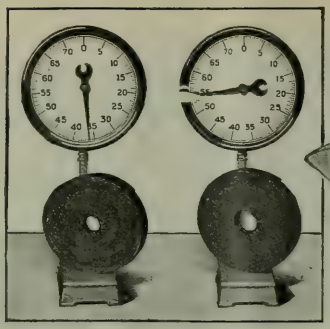
IT is only natural that car manufacturers should advertise the fact that their cars are Bower equipped. The buying public understands the full significance of such a claim.

BOWER
ROLLER BEARING CO.
Detroit Michigan

Exclusive Bower Features

Separate bearing surfaces for load and thrust. Parallel raceways. Self-aligning. Never need adjusting. Does not develop end thrust under loads. Will not bind or end-slip.

BOWER SAVES POWER



100 ft ordinary brake lining Weight 36 lbs. 4 oz.

100 ft. Thermoid Hydraulic Compressed Brake Lining Weight 54 lbs. 8 oz.

Thermoid has over *40% more material* by actual weight

Thermoid Hydraulic Compressed Brake Lining, when submerged in boiling water for one hour, absorbs only 8.7% of water — ordinary lining absorbs as much as 23%.

Make these brake lining tests yourself

Know that every foot of lining you install will give satisfactory service

Test No. 1. Cut off, equal length, pieces of brake lining you wish to compare and insert each in a quantity of boiling water. Keep the water simmering for one hour. It will be found that ordinary woven brake lining has absorbed enough water in this time to increase its weight 21% to 23%. Thermoid Hydraulic Compressed Brake Lining will have increased only 8.7%.

This test shows why brakes lined with ordinary lining, affected by moisture, swell and shrink and make constant adjustment necessary. Thermoid is made to resist moisture, oil and gasoline, by the exclusive process of *Grapnalizing*.

Test No. 2. Different makes of brake lining vary greatly in the amount of material per foot. To prove this, weigh a full roll of the same size of each kind. The heavy lining of a given size will wear much more slowly, because it is closer textured and contains more material. It must also wear down more evenly.

In this test Thermoid Hydraulic Compressed Brake Lining shows that by actual weight it contains over *40% more material* than ordinary brake lining.

Install Thermoid with confidence

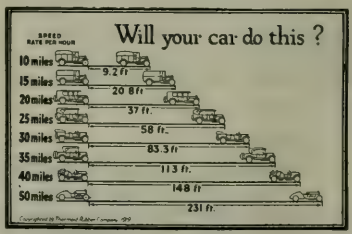
When you install Thermoid Brake Lining you know that it has been proved superior by scientific laboratory tests. It will not grab or slip even when worn down as thin as cardboard.

Because of its unfailing efficiency, the manufacturers of 50 of the leading cars and trucks use Thermoid.

Send for "The Dangers of Faulty Brakes." It contains valuable information which every engineer should know.

THERMOID RUBBER COMPANY
Factory and Main Offices: Trenton, N. J.

New York, Chicago, San Francisco, Cleveland, Atlanta, Detroit, Pittsburgh, Boston, London, Paris, Turin.



Famous Thermoid Standard Chart of stopping distances, now approved by Police Officials and Automotive Engineers. Chart shows distance in which car should stop if brakes are efficient Brakes lined with Thermoid meet these standards.

Ordinary woven lining

Notice the loosely woven texture

Wears down quickly and unevenly

Loses its gripping power as it wears

Thermoid Brake Lining

Hydraulic Compressed.

Notice the compact texture.

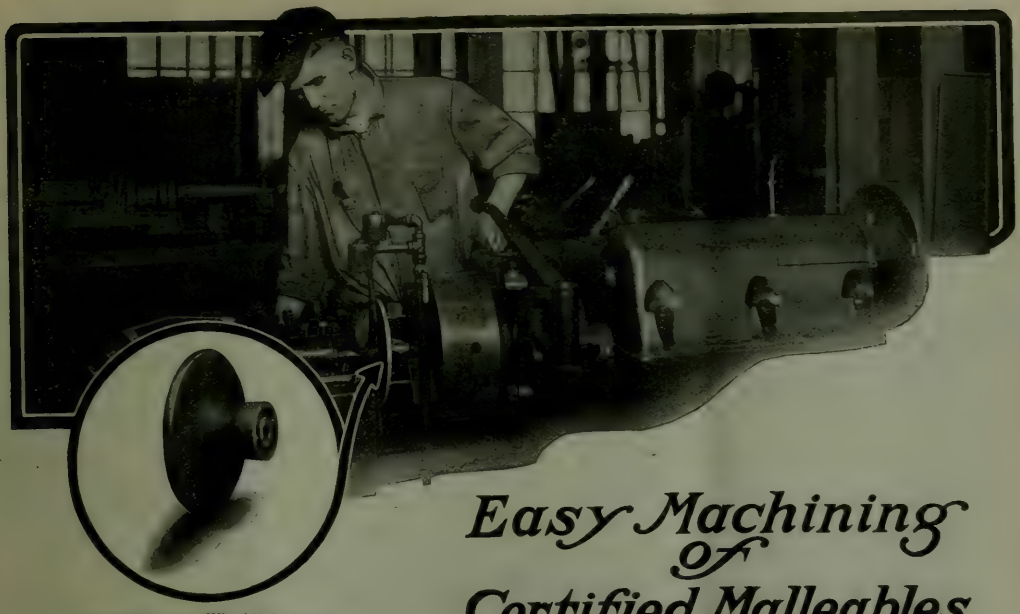
Wears down slowly.

Gives uniform gripping surface until worn wafer-thin.

Thermoid Brake Lining

Hydraulic Compressed

Makers of "Thermoid Hardy Universal Joints" and "Thermoid Crolide Compound Tires"



Automobile Rear Wheel Hub Flange

Easy Machining of Certified Malleables

In addition to great strength and high ductility, Certified Malleable Castings possess unusually good machining qualities.

Their machinability permits removal of the desired amount of metal in minimum time with minimum tool wear.

High surface speeds of 100 to 150 feet per minute with reasonably deep cuts are possible with Certified Malleables. This means much lower machining costs than with other ferrous metals of comparable shock and strain resisting qualities.

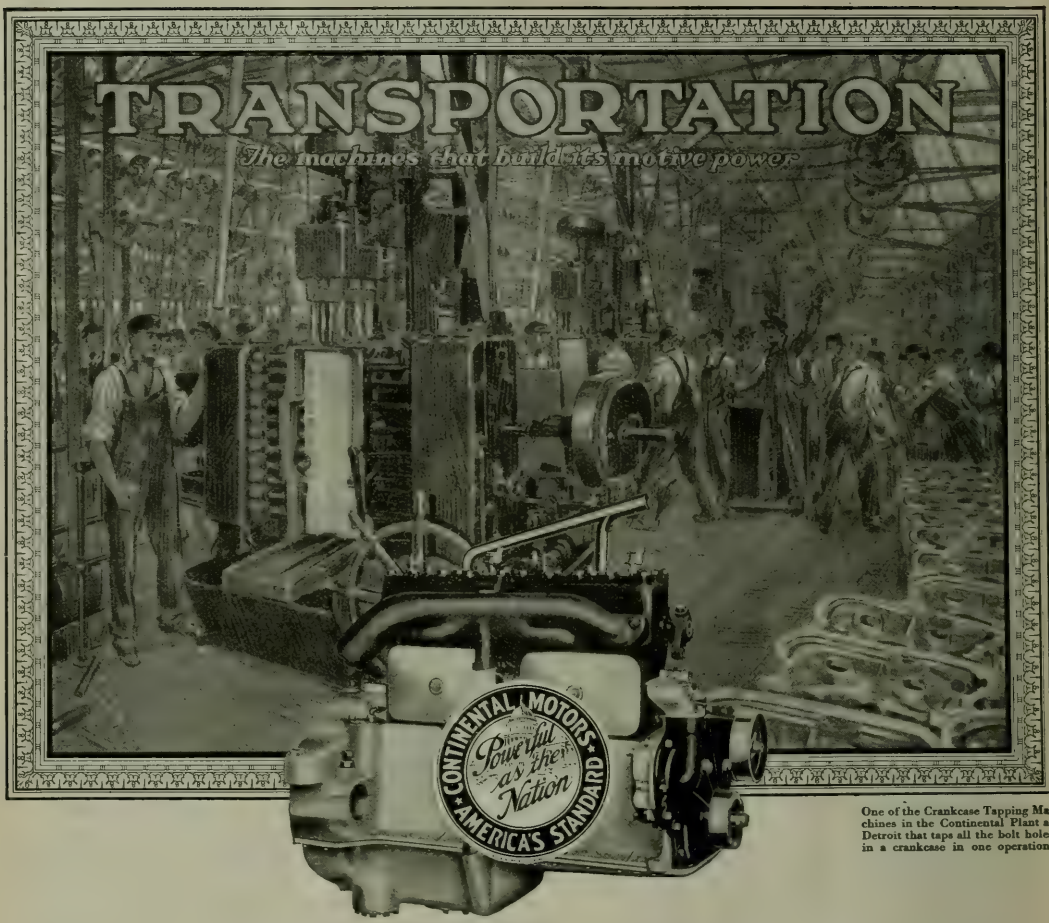
Certified Malleable Castings, the result of years of scientific research, are an important part of automotive construction. They are tough, strong and ductile. They perform their daily work where vibration is most severe, where breakage must be eliminated and where safety is essential.

Certificate holders listed here are manufacturers whose product for the quarter indicated has regularly met the requirements of the Association. In the judgment of the Association's Consulting Engineer, their plant practice is such as to produce uniform material of high character and integrity.

Members Receiving Certificates for the Quarter Ending March 31st, 1921

Albany Malleable Iron Co.	Albany, N Y
Albion Malleable Iron Co	Albion Mich
American Malleable Castings Co	Marion, O
American Malleables Co	Lancaster, N. Y. and Owosso, Mich.
Baltimore Malleable Iron & Steel Casting Co	Baltimore, Md.
Belle City Malleable Iron Co	Racine, Wis
Chain-Belt Co	Milwaukee, Wis.
Chicago Malleable Castings Co	West Pullman, Chicago, Ill
Cleveland-Moore Mfg Co	Cleveland, O.
Columbus Malleable Iron Co.	Columbus, O
Danville Malleable Iron Co	Danville, Ill.
Dayton Malleable Iron Co	Dayton, O. and Ironton, O
Derbie Mfg Co., Thomas	Philadelphia, Pa.
Eastern Malleable Iron Co.—	
Naugatuck Malleable Iron Works	Naugatuck, Conn.
Bridgeport Malleable Iron Works	Bridgeport, Conn.
Troy Malleable Iron Works	Troy, N. Y.
Wilmington Malleable Iron Works	Wilmington, Del.
Yalesa Iron Works	New Britain, Conn.
Erie Malleable Iron Co	Erie, Pa
Federal Malleable Co	West Allis, Wis.
Fort Pitt Malleable Iron Co.	Pittsburgh, Pa.
Frazer & Jones Co	Syracuse, N Y
Globe Malleable Iron & Steel Co	Syracuse, N Y
Hackett & Barker Car Co	Muncie, Cnty Ind
Illinois Malleable Iron Co	Chicago, Ill.
Iowa Malleable Iron Co.	Fairfield, Ia.
Kalamazoo Malleable Iron Co	Kalamazoo, Mich
Lacoma Car Co	Lacoma, N H.
Lakeside Malleable Castings Co	Racine, Wis.
Leh-Belt Co	Indianapolis, Ind
Marion Malleable Iron Works	Marion, Ind.
Mathie Malleable Iron Co	St. Charles, Ill.
National Malleable Castings Co.	Cleveland, O
Chicago, Ill., Indianapolis, Ind., Toledo, O., E. St. Louis, Ill.	
Northern Malleable Iron Co.	St. Paul, Minn.
Northwestern Malleable Iron Co	Milwaukee Wis
Pittsburgh Malleable Iron Co	Pittsburgh Pa
Rhode Island Malleable Iron Works	Hillsgrove, R. I
Rockford Malleable Iron Works	Rockford, Ill.
Rome-Mathias Foundries	Chattanooga, Tenn
St. Louis Malleable Casting Co.	St. Louis, Mo.
Saginaw Malleable Iron Co.	Saginaw, Mich.
Standard Malleable Castings Co	Terre Haute, Ind
Stowell Co	South Milwaukee, Wis.
T. H. Symington Co	Rochester N Y
Temple Malleable Iron & Steel Co	Temple, Pa.
Timken-Detroit Axle Co	Canton, O
Trenton Malleable Iron Co	Trenton, N J
Union Malleable Iron Co.	E. Moline, Ill.
Vermilion Malleable Iron Co.	Hoopeston, Ill.
Wamser Malleable Iron Co	Hammond, Ind
Watertown Malleable Iron Co.	Milwaukee, Wis.
Zanesville Malleable Co.	Zanesville, O

THE AMERICAN MALLEABLE CASTINGS ASSN.
The 1900 Euclid Building Cleveland, Ohio



One of the Crankcase Tapping Machines in the Continental Plant at Detroit that taps all the bolt holes in a crankcase in one operation.

Performance maintained over a long period of years has placed the Red Seal Motor in the niche it holds today in public confidence. What other factor could bring the public to the point where it selects a particular car or truck from the maelstrom of passing traffic and, with an all-sufficient gesture, says "It's equipped with 'The Continental Red Seal?'". ¶ But to the motor vehicle manufacturer, there are other important considerations that prompt the selection of the Red Seal Motor as standard equipment—the unequalled facilities of two of the largest and most completely equipped motor manufacturing plants in the world, the experience of an organization that has concentrated on motor manufacture for years and the bulwark of financial strength that the world knows is behind—The Continental Red Seal.

CONTINENTAL MOTORS CORPORATION

Offices: Detroit, U. S. A. Factories: Detroit and Muskegon

Largest Exclusive Motor Manufacturers in the World

Continental Motors

STANDARD POWER FOR TRUCKS, AUTOMOBILES AND TRACTORS

Two men used to take two minutes to get the 1912 model ready for the road. Today—press a button, snap a switch!

100% Electrified in 1921

Look back with us just ten years.

Recall the automobile with the "honk-honk" horn; with the acetylene tank strapped to the running board; dish-pan headlights with gas burners; dry cell, or perhaps magneto, ignition—while the controversy between "make-and-break" and "jump-spark" still raged. And forget not the crank, the tiresome, wearisome, sometimes dangerous crank!

Look now at your car of today, and see what ten short years have wrought. The horn, the lights, and the starting mechanism are all electrified, each made reliable and economical and safe. All the unwieldiness, the uncertainty, the inconvenience taken out of motoring, and instead, a simplicity and a satisfaction that require but the pressure of a button for their realization. To say nothing of a perfect ignition system thrown in for good measure.

In 1921, for the first time, every manufacturer of passenger automobiles in this country makes at least one model with in-built electrical equipment. Nothing that has happened in the automotive industry speaks more truly of progress than this.

Westinghouse, equipping more makes of cars and trucks electrically than any other manufacturer, contributor from the first to the electrification of the motor-driven vehicle, looks for a time when every truck and every tractor will be similarly modernized.

WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY
Offices in all Principal Cities · Representatives Everywhere

Always Demand Genuine Parts;
Beware of Pirate Parasites.

Westinghouse

STARTING, LIGHTING & IGNITION EQUIPMENT

Another feature of WOOD WHEEL engineering research that will work for the good of the industry

THE Research Engineering Division of the Automotive Wood Wheel Manufacturers' Association has just issued a comprehensive paper in which the method of storing and caring for Wood Wheels has been reduced to an exact science. This paper will be of immediate interest and value to car and truck makers, service station men and all owners of Wood Wheel equipped vehicles.

Even though Wood Wheels require very little attention and even though car and truck makers regard them as the very criterion of dependability, the Research Engineering Division of the Automotive Wood Wheel Manufacturers' Association spared neither pains nor expense in tracking down their minute characteristics so that methods for obtaining the greatest wheel efficiency at the lowest cost might be definitely formulated.

The findings of this research entitled, "The Care and Storage of Wood Wheels for Trucks," cover every phase of the subject from the time the timber is cut until it has rendered years of service in the wheel itself. It is thorough, semi-technical and complete. A copy will be mailed, post-paid, on your request.

AUTOMOTIVE WOOD WHEEL MANUFACTURERS' ASSOCIATION
105 West Monroe Street Chicago, Illinois

The members of this Association guarantee Wood Wheels of their manufacture for the life of the car or truck on which placed.

The Sign of the Service Station that is equipped for Wood Wheel servicing.

WOOD WHEELS for MOTOR VEHICLES

OVER 50,000 MILES

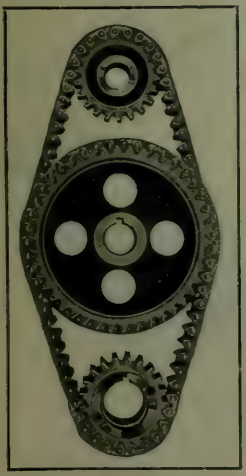
NOW REPORTED ON

"WHITNEY"

HIGH EFFICIENCY

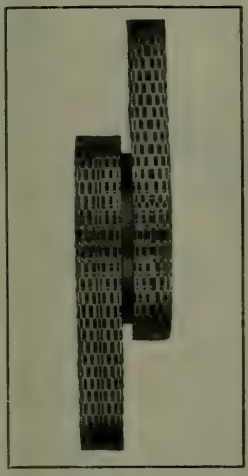
FRONT END MOTOR CHAIN DRIVES

AND STILL IN GOOD CONDITION



Not one of these chains has been known to skip a sprocket tooth

Chains having a high mileage save inconvenience and frequent replacement expense.



THE WHITNEY MFG. CO.

HARTFORD, CONNECTICUT, U. S. A.

RICH TOOL COMPANY

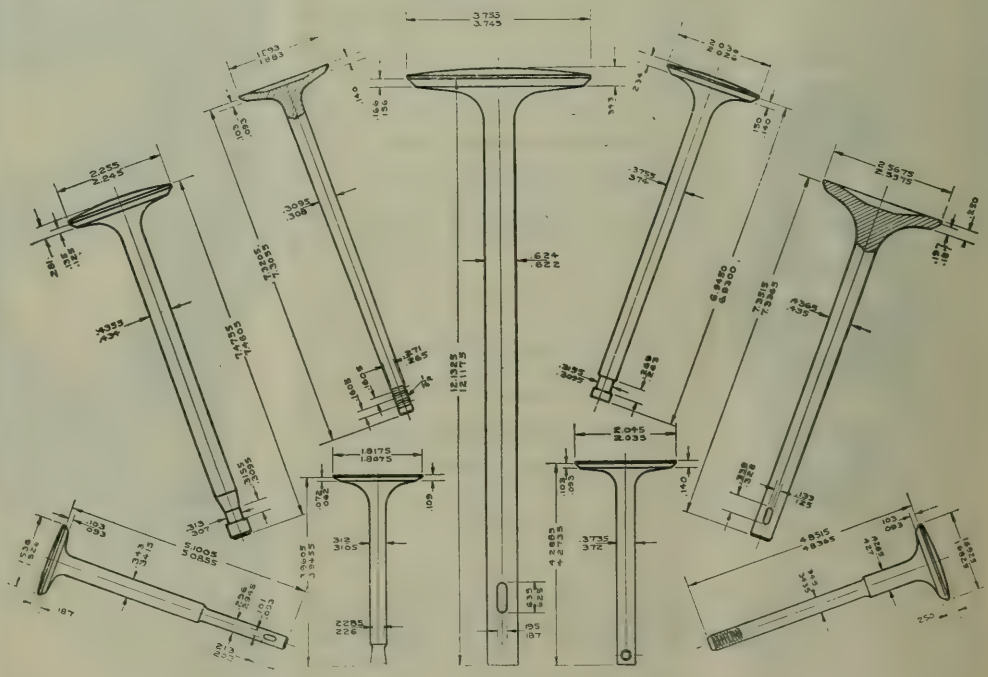
Railway Exchange Bldg., Chicago, Ill. **Kresge Building, Detroit, Mich.**

The cuts below represent valves used in some of the best known present day Aeroplane, Motor Boat and Racing Automobile Engines. They are all products of this Company and most of them have been produced in large quantities and have, therefore, been thoroughly tested in service.

Needless to say, they are all Tungsten Steel, but we also make one-piece forged valves of all other commonly used Alloy Steels, in the manufacture of which we exercise the same care as is used in our Tungsten Valve materials.

One of the newer types of valves which we have been making in very large quantities for the past two years is our Hi-Chromium Valve, which has some very remarkable properties. It is for some purposes an excellent valve and we solicit inquiries from those who are troubled by a persistent burning away of the seats of the valves in their motors.

We also have a material called Cobalt-Crom that possesses the qualities of High-Chromium as relates to resistance to burning, together with a resistance to abrasion or wear and a strength when red hot more nearly comparable to that of High-Tungsten. This material offers excellent promise of good results in engines running for long periods under heavy load without attention, such as marine motors and tractor motors.

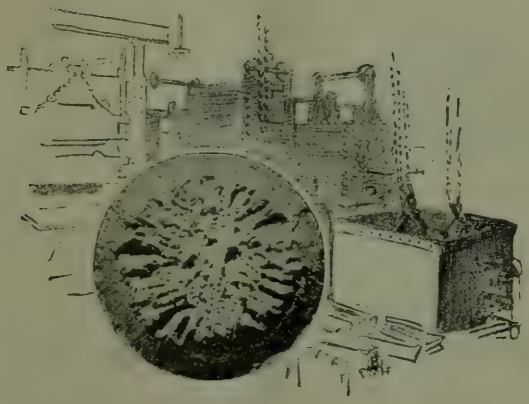


Our Engineering Department is at your service on all questions concerning suitability of material and design.

UMA 2

THE EXACT STEEL OF MANY USES

Responds 100% to Heat Treatment



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Our Uma No. 2 is a perfectly homogeneous and uniform steel and therefore has a wide range of quenching and drawing temperatures.

These properties insure unvarying physical characteristics in the heat treated product.

Would you like to have our metallurgical engineers study your peculiar problem?

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The Elimination of

Vibrations

Caused by Lack of Balance,
Is the DUTY of Every Auto Manufacturer.

WE SOLVE MA VIBRATION PROBLEMS
Trade Mark Registered

HE knows, and his engineers know, that engine **vibrations,** caused by unbalanced crankshaft or flywheel, create discomfort.

What he may not have known, with certainty, was How to Eliminate that Vibration.

He can solve the problem, with certainty, with the aid of an MA **Balancing Machine,** which will correctly balance his crankshafts and flywheels.

We say, **"With Certainty,"** because during the past four years of all the MA Balancing Machines that have been placed in use not one has failed to give absolute satisfaction—not one has been returned for any reason.

MA Balancing Machines bear our trademark MA, the initials of Mr. N. W. Akimoff, president of the company.

VIBRATION SPECIALTY COMPANY

Harrison Building **Philadelphia, U. S. A.**

PRESSED STEEL FRAMES

FOR

Passenger Cars, Trucks, Tractors, Trailers

ALSO

Heavy Miscellaneous Stampings of all kinds

Frame Makers for Cars of Quality Since 1904

PARISH & BINGHAM CORPORATION

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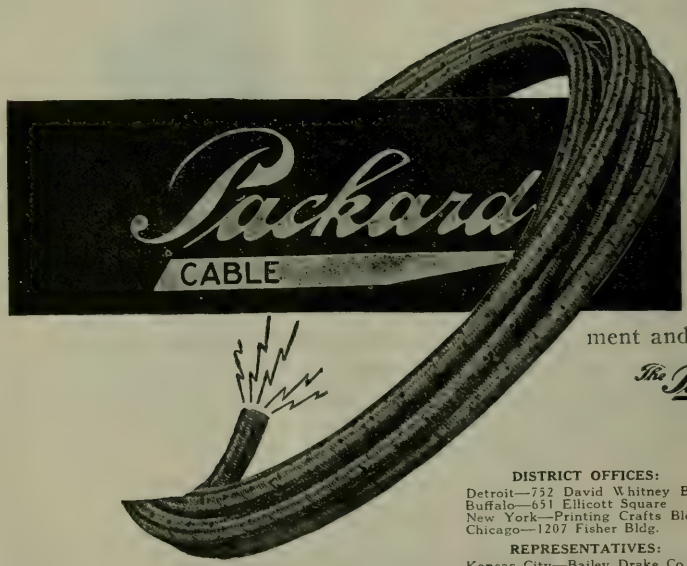

Packard Cable gives real service. Service means satisfaction. Satisfaction means future sales. The wiring system of a car is one thing that does not need adjusting. It needs real quality cable first, last and all the time.

There is a standard style of Packard cable for every automotive requirement and for every make of car.

The Packard Electric Company

Warren, Ohio

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I & M GREESGUN

A *Necessity* on Every Car

If the buyers of your cars are to get full value—if your cars are going to depreciate but slowly—if wear is to be kept down—**GreesGun** equipment is a **necessity,** not merely a desirable feature.

The I & M GreesGun is convenient. Hence it is used frequently and regularly.

It is positive, 500 to 1000 pounds pressure is easily put back of the grease.

It is clean. Check valves in both Gun and nipples make messiness impossible.

It is strong. There is no hose or other easily injured part.

It is quick. Its use is easy; and when it must be refilled, it takes but a few minutes.

We shall be glad to prove all this to you—to send a representative or to send the gun for testing. We know your decision will be that it is a necessity on your cars.

Booklet "Positive Lubrication" will be sent on request. It gives, in detail, the story of this better method of chassis lubrication.

Made and guaranteed by **The Ireland & Matthews Manufacturing Company**

Beard and Chatfield Streets, Detroit, Michigan

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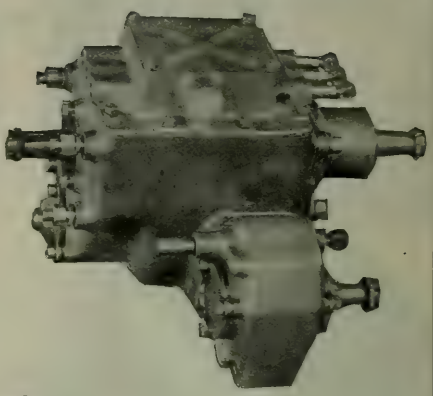
FULLER
TRANSMISSIONS



The use of the Fuller Power Take-off with Fuller Transmissions gives an opportunity for increasing the range of motor trucks considerably. Log loaders, Specially equipped Telephone Co. trucks, Crane equipped trucks, are only fore-runners.

Manufacturers of clutches, controls and transmissions exclusively

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QUALITY Fuller FIRST

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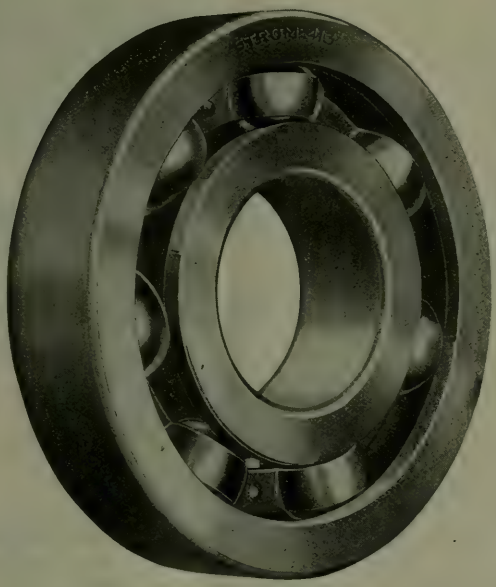
No Adjustments Required

Once the correct Strom Bearing is selected to carry the required load and has been properly installed, whether it is radial or thrust or a combination of these, the bearing will wear for the life of the car with practically no attention. Automotive engineers appreciate the advantages of a bearing that requires no adjustment. Our experts will help select the right bearing for your installation.



U. S. Ball Bearing Mfg. Co.
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4533 Palmer St. Chicago, Ill.

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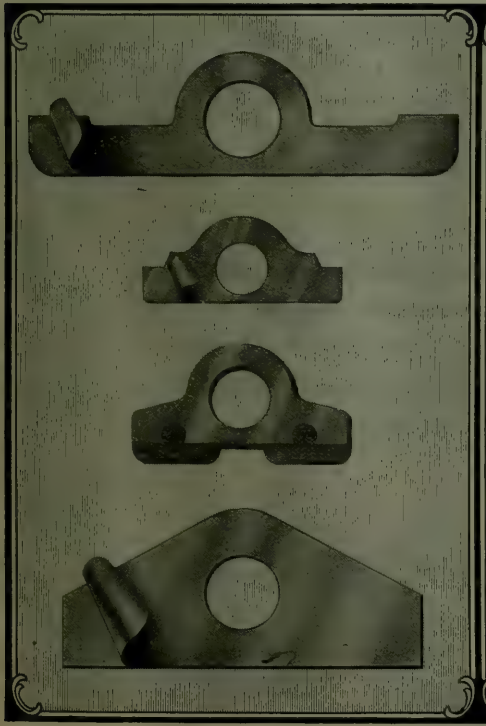

Peel 'Em Down !

Laminated Shims make bearing assembly the simplest of production problems. Adjustment to .002 inch is simply a matter of peeling off the brass layers. After sales upkeep is equally simplified. Our manufacturer customers incorporate Laminated Shims in their own literature as a selling point.

Furnished die cut from sheet Laminum in shapes, thicknesses, and laminations to order. Babbitt-faced to make an all babbitt bearing if desired. Let us figure on your requirements.

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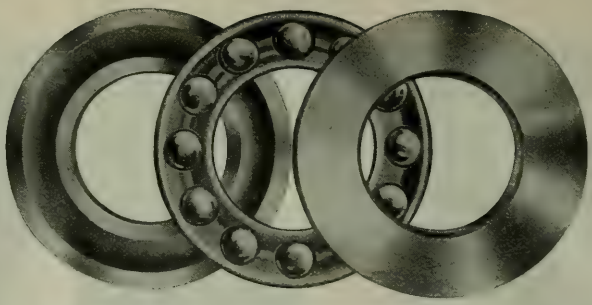
LAMINUM



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Manufacturers of Thrust Ball Bearings of all types.

Let our engineers help to solve your Thrust Bearing problems.

Drop Forgings.

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Whether in the design of a new machine

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The operation of one in service
We can effect economies.

Submit us your problems.
Our Engineering Service entails no obligations.

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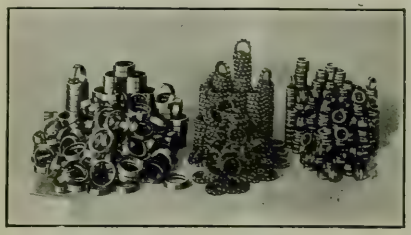
NORMA

INTERCHANGEABILITY

Here is a pile of "NORMA" outer races—
a pile of "NORMA" cages with balls—
and a pile of "NORMA" inner races



You may select any outer race from this pile.

And any cage with balls from this pile.

And any inner race from this pile.

Put them together—and you have a perfect "NORMA" Precision Ball Bearing—accurate as to size and dimensions and alignment—perfect as to true and silent running—as "frictionless" as a ball bearing can be made.

This is "NORMA" interchangeability—and we believe there is nothing to equal it in the world of ball bearings.

Do you know of any other ball bearing that can be assembled from stock this way—and still be a perfect bearing?

Think what this means in facilitating that progressive assembling which reduces costs and increases production.

THE NORMA COMPANY OF AMERICA

Anable Avenue, Long Island City, New York

Ball, Roller, Thrust and Combination Bearings

Positions & Men Available

The following announcements are published for the benefit of members of the Society and the convenience of companies in need of men. No charge whatever is made for this service. In the case of items prefixed by an asterisk further information is withheld at the request of the company or individual making the insertion, but written communications bearing the number of such items will be forwarded by the S. A. E. Office. In other cases further information will be supplied by the Office of the Society. Applications for positions from non-members must be endorsed by a member of the Society.

0024 DESIGNING ENGINEER, with 19 years' experience in designing and developing electrical apparatus, mostly magnetos and kindred apparatus including telephones and switchboards.

0050 GRADUATE ENGINEER with business training desires to make a connection with a progressive organization in a capacity leading to an executive position. Has worked one year as mechanic and two years on production, testing, technical correspondence and sales. Age, 26. Prefer middle west territory.

0051 SPRING MAN A practical engineer who has been ten years in the chassis spring trade and has had an extensive road experience is ready to take charge of design, production, field or experimental work. Can develop the special machinery required to produce efficiently on a large scale.

0052 FACTORY OR PRODUCTION MANAGER, with 12 years' practical experience in automobile and parts manufacturing plants and familiar with costs, production, planning, purchasing and plant engineering, eight years in executive positions, desires to connect with a company where initiative, energy and ability are appreciated. Age 36. Married.

0053 GRADUATE ENGINEER AND METALLURGIST, experienced in axle and chassis design and familiar with modern production methods and heat treating, will be open for new position in 30 to 60 days. Best of references from past and present employers.

0054 AUTOMOTIVE ENGINEER, 33 years of age, with designing experience, possessing good personality and ability to meet people, and now in second year of evening law school, desires to represent or associate with manufacturer's representative in Detroit. Best of references.

0055 INDUSTRIAL EXECUTIVE with eight years' experience in the operation of modern factories producing pressed, rolled and welded parts. Also experienced in selling, maintenance, development and design of machines. Possesses a knowledge of accounting and production control.

0056 MECHANICAL DRAFTSMAN Technically educated and experienced on passenger car and truck detailing and layout work, lately engaged in the layout and design of passenger-car and truck axles, desires a position with motor-car builder at Detroit or Cleveland.

(*Continued on page* 52)

New Process Gears

Cut steel gears—Spurs, Straight Bevels and Spiral Bevels—for transmissions and drives, also complete Differentials

***for* Automobiles Trucks and Tractors**

correctly and economically made by 10 acres of latest type machinery.

Our engineers are ready to confer with you.

Quality—Quantity—Quickness

Member of the

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The permanent, accurate alignment of the Schatz Universal goes far to eliminate friction and adds greatly to the life of the machine, as well as of the bearing itself.

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***Schatz* UNIVERSAL BALL BEARING**

For All Insulation *Vul-Cot* Fibre

Machines as readily as lead

VUL-COT Fibre comes in sheets, rods and tubes. It's dense and tough and has an extremely low friction co-efficient. This gives it the greatest wear resistance of any insulator.

VUL-COT Fibre is always uniform—never contains fissures, hard or soft spots, grit or other foreign matter. Edge tools used in machining it are subjected to little wear. Here are the physical properties of *VUL-COT* Fibre:

Tensile strength 9,000 to 14,000 pounds per square inch—compressive strength 32,000 to 67,000 pounds per square inch—resistance to shearing 9,000 to 13,000 pounds per square inch—specific gravity 1.2 to 1.5. Electrical rupture 100 to 400 volts per mil.

—And these are the properties that have made *VUL-COT* Fibre "The Material with a Million Uses." We have a book bearing this title. We'll send it: Tell us where. Also consult the *VUL-COT* Service Dept. in your individual problems.

BY INVITATION MEMBER OF

AMERICAN VULCANIZED FIBRE CO.

521 Equitable Bldg., Wilmington, Del.

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BOSTON NEW YORK PHILADELPHIA PITTSBURGH CLEVELAND DETROIT CHICAGO ST LOUIS

Complete Stock for Immediate Shipment at Chicago

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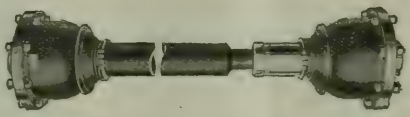
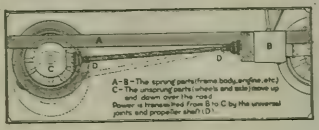


SPICER equipped vehicles are in high favor with two great classes of experienced motorists: those who are so situated financially that they buy the best from force of habit, and those whose means require them to buy the best for reasons of economy.

Write on your business letterhead for booklet concerning Spicer Universal Joints and Propeller Shafts.


A
B
C
D
A–B—The sprung parts (frame body, engine, etc.)
C—The unsprung parts (wheels and axle) move up and down over the road
Power is transmitted from B to C by the universal joints and propeller shaft (D).

SPICER MANUFACTURING CORPORATION—SOUTH PLAINFIELD, N.J.

Spicer

UNIVERSAL JOINTS AND PROPELLER SHAFTS

MEN AVAILABLE
Continued

0057 PRODUCTION MANAGER AND ENGINEER with 15 years' experience in the building of passenger cars and trucks, desires a position of a similar nature or as assistant to the general or works manager. At present production manager of a large automobile firm.

0059 MECHANICAL, AUTOMOTIVE OR SALES ENGINEER Technical graduate of executive ability and broad experience and capable of taking entire charge of engineering and experimental departments of large truck, tractor or engine firm, wishes to become associated with an organization where past experience can be utilized. Fifteen years' technical and practical experience on automotive engines, automobiles, trucks, tractors, special machinery, tools, etc., both in engineering and production departments.

0060 SERVICE MANAGER with 18 years' experience in factory and large service stations on passenger and commercial cars. Personal interview desired.

0062 EXECUTIVE wishes to join a live business organization. Experienced in engineering and production departments, purchasing and general plant supervision in shops employing 200 men.

0063 PRODUCTION ENGINEER OR SHOP SUPERINTENDENT wishes a position with an automobile or truck builder. Over 15 years' practical experience. Prefer Detroit or vicinity, but would consider other locality.

0064 ENGINEER capable of designing and putting in production a line of trucks or tractors. Position as chief engineer or chief draftsman with new truck or tractor company is desired.

0066 ENGINEER Technical graduate with 11 years' practical experience, 5 years in truck design and construction. Has held positions as truck designer, chief draftsman and chief engineer. Capable of organizing and systematizing an engineering or production department so as to produce maximum results with minimum labor and expense. Open for an executive position with a responsible truck company.

0067 ENGINEER Desires position with progressive company to take charge of engineering, designing, experimental and research work and assist sales and advertising departments in preparation of useful reliable data. A broad-minded college graduate and designer of successful engines. Experienced on all parts of automobile and truck chassis design and dynamometer tests.

0068 MECHANICAL DESIGNER with 10 years' general design work and five years gasoline engine design experience at present occupying position of assistant general superintendent wishes a position with firm building power farm machinery or doing truck work. Design or production department preferred.

0070 AUTOMOTIVE ENGINEER with 15 years' experience in the design, construction, testing and production of automobiles, trucks and their component parts. Energetic with executive ability and originality. At present engineer for large Eastern manufacturer of lighting, starting and ignition equipment. Would consider position as engineer or sales engineer with progressive organization.

0071 ENGINEER Executive with 12 years' automobile experience as designer, engineer, chief inspector and assembly superintendent and capable of organizing and managing these departments. Familiar with principles

(*Continued on page* 54)

Johns-Manville Automotive Equipment

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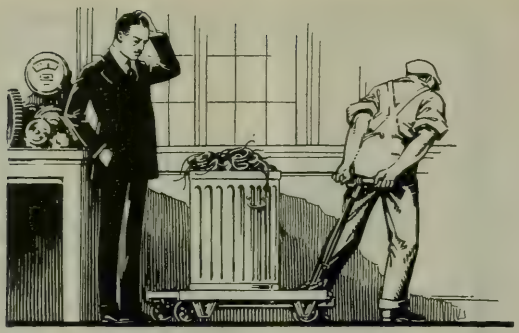

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AcmeWire

"It goes in the space"

MEN AVAILABLE
Continued

of factory organization. Excellent references. Detroit preferred.

0072 ENGINEER Technical graduate. Twelve years' experience in internal-combustion engines including aviation engines. Capable of taking charge of assembly, experimental, production, testing, designing and layout work. Desires to make connection with a reliable and progressive corporation.

0073 MECHANICAL DRAFTSMAN Experienced in motor-truck layout work and checking; also shop experience. Technical graduate. Newark, New York City or vicinity preferred.

0074 AUTOMOTIVE ENGINEER Technical graduate experienced in chassis design and layout, axles, gas engines, research and experimental work. Familiar with general body layout in proper relation to chassis. Age 25. Married.

0075 ENGINEER, an accepted authority on automotive design and development work with 20 years' practical experience will give his services for a few months to assist manufacturers in the solution of their problems.

0076 SALES ENGINEER with headquarters at Detroit desires to represent manufacturers of wood and metal patterns, gages, jigs and fixtures, forgings, stampings, grey iron and malleable castings, production tools and screw-machine products. Territory covered Michigan, Illinois, Indiana, Ohio, Pennsylvania and New York.

0077 RESEARCH ENGINEER, capable of scientific investigation or development of unperfected devices. Competent on any mechanical problem; inventive; with wide designing experience supplemented by the authorship of technical articles and teaching. Specialty internal-combustion engines. Age 36, married.

0078 CHIEF ENGINEER OR ASSISTANT Graduate mechanical engineer, age 27, with six years' experience in the design, development and application of various types of automotive engine, desires to return to passenger-car field. At present holds responsible engineering position with engine builder and wishes a similar place with a progressive automobile company. Available on reasonable notice.

0079 WORKS MANAGER, having broad experience in the management of plants employing from 500 to 3000 men for last 16 years is available for immediate engagement. Experience includes automobile parts of various kinds, steam turbines and powerplant auxiliaries. Practical man and good organizer. Age 38.

0080 DESIGNING ENGINEER AND FACTORY MANAGER with 13 years' experience in the automotive industry in production and tool engineering and factory management and good technical and practical training. An American, 33 years old. At present chief engineer and assistant factory manager. Has held responsible positions with well-known companies in the industry. Would like a position with a progressive company.

0081 MECHANICAL ENGINEER with 12 years' experience in the design and manufacture of automotive equipment, capable of taking full charge of the designing of tools, dies, jigs and fixtures and factory equipment for quantity production of steel bodies for trucks and pleasure cars.

(*Continued on page* 56)

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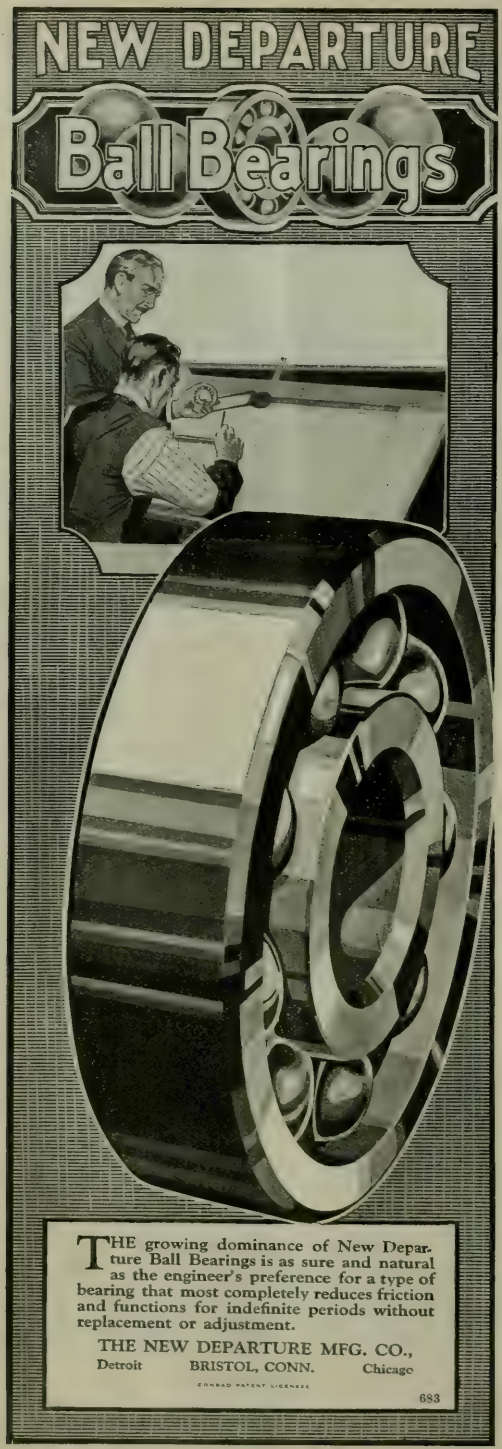
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MEN AVAILABLE
Continued

0082 DESIGNING DRAFTSMAN would like opportunity to branch into the selling field. Has had 2 years' automobile and 8 years' mechanical experience. Willing to go anywhere. Age 29.

0083 ENGINEERING EXECUTIVE. University graduate with 9 years' experience in design, factory layout work and plant engineering, laboratory and experimental work and general factory inspection, desires to make new connection with broader opportunities. Thoroughly experienced in industrial organization and production methods. Several years' experience in sales engineering and service.

0084 EXECUTIVE DEVELOPMENT ENGINEER. Graduate mechanical engineer with textile engineering experience. Last 10 years with a large progressive tire company. Is thoroughly familiar with tire design, production and sales methods, has initiative and is capable of organizing and getting results.

0085 GRADUATE MECHANICAL ENGINEER. Ten years in rubber tire manufacturing including 3 years as factory representative abroad. Also had extensive airship engineering and testing experience during the war and is not restricted to the rubber business. Sales engineering or financial lines preferred. Age 32; unmarried. Will go anywhere in the United States.

0086 ENGINEER with 10 years' experience in the design and development of automotive equipment including gasoline and electric trucks and tractors. Prefers to locate in the east. Age 31. Available July 1.

0087 DESIGNER wishes a position with a progressive company. Experienced in the complete design of automobiles and trucks and has had 14 years' experience in the development of automobiles, airplanes and marine engines.

0088 DESIGNING ENGINEER. Progressive and thoroughly competent to take charge of design and development work. Has spent 8 years in the motorcycle industry and is well acquainted with automobile design. Available on short notice.

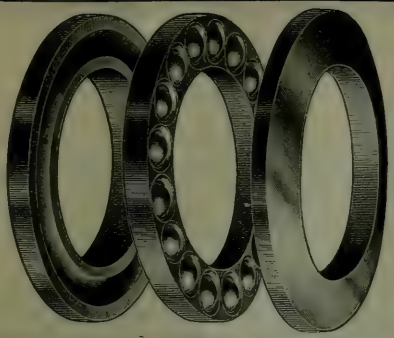
0096 AUTOMOTIVE ENGINEER desires a position as chief engineer or assistant with commercial or passenger car company. For the past 2 years has been chief engineer with a truck building company with full charge of all design, inspection and experimental work. Location preferred, Illinois or Indiana.

0097 MECHANICAL ELECTRICAL ENGINEER Technical and practical executive with 20 years' experience in designing, shop supervision and materials. Has ability to produce from designing through experimental and manufacturing stages. For past 5 years with a large manufacturer in the lighting and magneto field. Capable of holding a position as chief engineer.

0098 MECHANICAL DRAFTSMAN with technical education and six years' experience, desires a position in New York City or vicinity. Experienced in the design and detailing of passenger cars and motor trucks. Age 23. Married.

0099 BODY OR ASSISTANT CHIEF ENGINEER with European education and training and eight years' practical experience in complete car design; chassis and body, specializing in body engineering, including supplementary body and sheet metal parts and all depart-

(*Continued on page* 58)



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ments concerned. Able to assume charge of body designing, engineering and experimental division of an automobile or body plant. At present holds a similar responsible position with company building high-grade cars. Best of references can be furnished.

0100 CHIEF DRAFTSMAN with firm of consulting and automotive engineers, who has had 10 years' experience in passenger-car, truck and tractor design and production; will consider a position as engineer or assistant engineer with well-established firm in the Middle West. Age 30. Married.

0101 MECHANICAL ENGINEER Technical graduate; 33 years old, married, with 12 years' experience in designing and building automobiles, including racing cars. Has developed and built a high grade four cylinder light car and is at present employed as chief engineer of an automobile company.

0102 MECHANICAL ENGINEER with 18 years' experience desires to get in touch with progressive automobile builder who is in need of a man familiar with quantity production. St. Louis preferred.

0103 ENGINEER AND EXECUTIVE Practical man with 12 years' experience in the construction of commercial and passenger vehicles and gasoline engines and an authority on internal-combustion engines who can organize and direct. Is now connected with large automotive corporation as assistant engineer and superintendent, but desires a position with a greater future. Would serve as assistant. No preferable location. Good references. Available on reasonable notice.

0104 SALES ENGINEER wishes to represent manufacturer of automotive parts in the Rocky Mountain territory and on the Pacific coast. Has had 15 years' experience in sales, service, engineering and production in automotive and allied lines. Now located in Oregon. Age 36. Married.

0105 ENGINEER Technical man with 10 years' experience in design, experimental work and production of various grades of passenger cars is open for a position with a progressive firm as an executive or assistant. Willing to represent parts manufacturer as sales engineer. Good references.

0106 METALLURGICAL ENGINEER desires new connection as director of research department. Has had extensive experience in heat-treating, foundry and steel mill practice and is also familiar with shop problems and cost accounting and production systems. Qualified to fill an executive position. Can furnish the best of references.

0107 EXECUTIVE with 11 years' experience as an executive and engineer in automobile and aviation engine plants, a thorough technical education and broad experience. Possesses the ability to organize and handle men and is progressive and confident. An excellent correspondent, clear thinker and hard worker. Eastern location preferred. Available in July.

0108 ELECTRICAL AND MECHANICAL ENGINEER Experienced in testing, automotive design, inspection, sales and research work for six years. Is qualified to act as assistant sales manager, assistant chief engineer or

(*Continued on page* 60)

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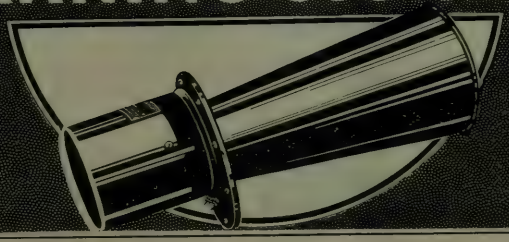

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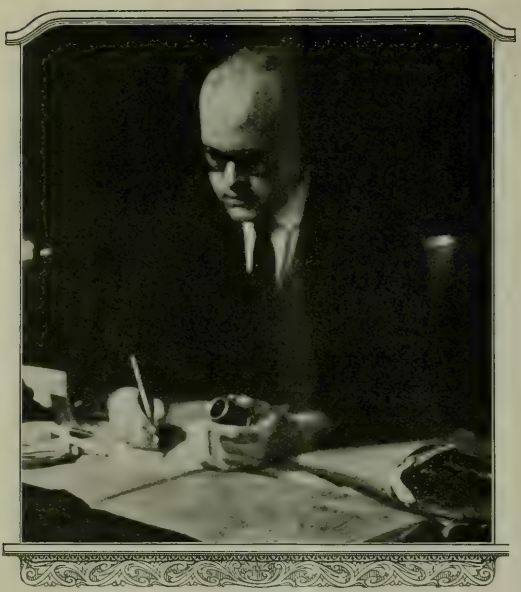

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MEN AVAILABLE
Concluded

director of purchasing. East preferred but not essential. Age 27. Married.

0109 EXECUTIVE with eight years' experience in the production, assembly, testing and repairing of automobiles and automobile and aeroplane engines. Location, New York or New Jersey preferred.

0110 YOUNG MAN wishes to connect with a company building passenger cars to learn the business and be trained for position as an engineer. Experienced in drafting, design, layout work and repair. Age 23; unmarried.

0111 YOUNG ENGINEER University graduate with experience in designing, drafting, assembling and testing. Age 23; unmarried. Location no object. Available at once.

0112 SALES ENGINEER College man with broad practical experience and successful record would like to get in touch with progressive automotive organization which has an opening for a man of initiative and ability in that capacity or as service executive.

0113 SALES ENGINEER Graduate mechanical engineer with experience in directing wholesale and retail sales and service departments in automobile business is available for position with sales organization in the same or a similar line of business. Age 30; unmarried.

0114 GRADUATE ENGINEER who has had 10 years' practical experience in designing, production, experimental engineering, drafting and as an executive wishes to make a connection with a progressive firm where a good future is dependent upon work and ability. Available at once. Age 30.

0115 AUTOMOTIVE ENGINEER University graduate with four years' experience in engine assembling, electrical repair work, experimental testing and production. Unmarried. Prefer Eastern location.

0116 PRODUCTION MANAGER or shop superintendent with eight years' experience in experimental, factory cost, planning and modern personnel work. Has had a college education. Age 30; married.

0117 ENGINEER Experienced in accessory and truck design and also in editorial, advertising, publicity, service and sales work. Age 30; married. Available at once.

0118 AUTOMOBILE ENGINEER with 15 years' experience in all lines of automobile engineering. Age 35. Available at once. Prefers to locate in Middle West.

0119 EXPERIMENTAL ENGINEER A keen, energetic, reliable, broadminded man with 20 years' practical experience in various executive capacities covering development, experimental and production work, desires to make a permanent connection with a progressive organization where initiative, ability and energy will be appreciated. Has been associated with leading engineers and largest firms in the industry. Can serve in capacities of experimental supervisor, special representative of general manager, superintendent and assistant to chief engineer. Prefer Detroit or Cleveland but would consider any other locality. Age 39; married.

0120 TRANSPORTATION ENGINEER with sales and engineering experience desires to become associated with a company building a quality truck. Is capable of acting as assistant to sales manager. Technical graduate.

(*Continued on page* 62)

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have been "Listed as Standard" by Underwriters' Laboratories. Breast drill and wrench are the only tools required to apply any of our equipment.

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95 TECHNICAL GRADUATE with sufficient practical experience to qualify as an instructor on any part of an automobile, truck or tractor. Location, New Jersey. Government position.

111 INSTRUCTOR Man with a thorough knowledge of automotive electrical equipment. Must be young and possess ability to handle young men. An ex-service man would fit in well if he had the necessary qualifications

113 BODY HARDWARE MANUFACTURER is in need of a representative to call on automobile trade in Illinois, Wisconsin and Missouri as a side line.

114 SALES AND ADVERTISING MANAGER for a new automatic thermostatic control of electric cooking devices invented by automotive engineer. Operations to be confined to the Middle West for the first year.

116 SALESMEN who have initiative, strong personality and who have been in direct contact with the buying public are desired to sell passenger cars on a commission basis.

*117 DRAFTSMAN with experience in the design of electrical ignition and lighting systems. Man with a thorough knowledge of this work and who can make complete designs to meet special conditions is wanted. Full information should be given in the first letter.

*118 FIRST-CLASS BODY ENGINEER, capable of executing body designs of all descriptions, superintending the construction of sample bodies and writing out complete specifications. Man having experience with body framework and metal laying out; one who is familiar with painting, upholstery and general manufacturing specifications. In other words, a man to assume complete charge of all body engineering of the company. Must have 10 years' experience at least.

*119 INSPECTION ENGINEER One who has had at least 10 years' experience with high-grade engine builders, more especially eight-cylinder V-type engines; an executive who can generally supervise the entire inspection of the building of such engines and is absolutely familiar with the best practice.

120 DESIGNING ENGINEER with A-1 references is desired by a Colorado builder of steam vehicles.

121 MACHINE SHOP FOREMAN for plant building steam cars.

126 INSTRUCTORS IN EXPERIMENTAL ENGINEERING. Graduates in mechanical engineering who have specialized in automobile engineering preferred. Location, Georgia.

127 SALESMAN who is in close touch with automotive engineers is desired, to introduce to the industry several laboratory devices including a high-speed balanced diaphragm type indicator.

130 YOUNG MAN between 25 and 35 to fill a vacancy in the sales and advertising department. Must possess strong personality and be of good character. Experience in sales and engineering work preferable but not essential. No traveling at present but some later on if occasion demands. A good organizer is desired.

133 SALES REPRESENTATIVE wanted by manufacturer of gears for the automotive trade. One who is acquainted with the trade preferred. Salary and commission basis. Headquarters in Detroit. State age, experience and previous connections.

134 ENGINEER for sales development and advertising work is desired by a manufacturer of high-class gears. Salary and commission basis. Headquarters in Boston. State age, experience and previous connections.

(*Concluded on page* 64)

*See announcement at the head of the "Positions and Men Available" column, page 50.

FOUNDRY DEPARTMENT

Even aeroplane manufacturers are using our foundry department more and more. For we are specialists in the casting of

Aluminum, Bearing Metals
Manganese & Phosphor Bronze
& All Non-Ferrous Metals

Let us estimate on your next order.

"Quality" Die Castings

Have you given a try-out yet to "Quality" Die Castings?

Motor and Transmission Department

"Quick on the getaway"—always said of the L. M. F. Motors with exclusive "HOT-SPOT."

We carry out your specifications in making transmissions, gears and other motive parts.

LIGHT MFG. & FOUNDRY CO.
Pottstown, Pa., U. S. A.

SIMPLICITY-RUGGEDNESS
EFFICIENCY-ECONOMY
Always associate these Qualities with

TEAGLE MAGNETO

A BETTER SPARK IN A SIMPLER WAY

Conforms to S. A. E. Standards
THE TEAGLE CO., Cleveland, O.
You want to know more about this *simplest* magneto—write 1128 Oregon Avenue for details.

How the Aico Engineering Department Can Reduce the Cost of Your Molded Parts

The Aico method of cold molding electrical parts and automotive units reduces cost and produces work of the finest quality.

Radiator caps produced by the Aico cold molding process carry the maker's personal guarantee that they will not warp, crack or change in color. Aico caps are not affected by heat or anti-freeze mixtures.

Our Engineering Department is operated for the use of all consumers of cold molded insulations, and we will welcome an opportunity of discussing your molding problems and offering possible suggestions for more practical production designs with resultant reduction in molding costs.

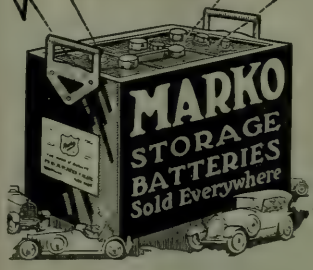
American Insulator Corp., New Freedom, Pa.
Chicago Office: 564-570 West Monroe Street.
Detroit Office: 836-840 Cherry Street.
Montreal Office: 103 Notre Dame Street, W.
New York Office: 120 Broadway.

DEALERS EVERYWHERE

are reaping a harvest of Big Profits selling the MARKO STORAGE BATTERY—First in exclusive features—First in salability—Last to wear out

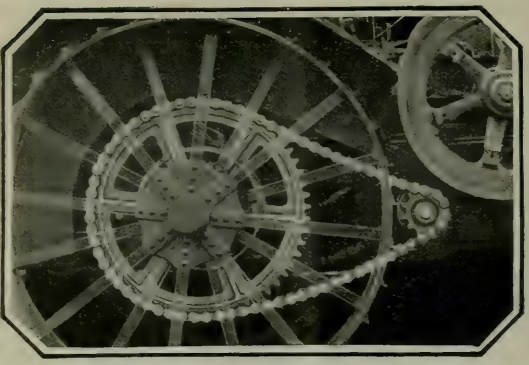
FIRST!-
Because They Out-last All Others

Pin this in Your Memory!



All Standard MARKO BATTERIES have heavier positive and correspondingly thinner negative plates assuring a more evenly balanced element which absolutely prevents buckling and greatly increases the life of the battery.

PAUL M. MARKO & CO., INC.
Main Office and Works
1402-1412 Atlantic Ave., Brooklyn, N. Y.



Baldwin Chain Drive Used on the I H C "Titan" Tractor

In the Farm Implement Field—

Long ago, Baldwin chain drives made their mark in the farm implement field. Since that time, their almost universal use by leading implement manufacturers— as a final drive on their tractors and in many and varied applications on implements— has been a lasting testimonial of their unfailing dependability and their long, carefree life.

BALDWIN DISTRIBUTORS

Boston, Mass. ..... Walter H. Williams, 175 Massachusetts Ave.
Buffalo, N. Y. ..... Baldwin Service Co., 262 Oak St., Pierce J. Fleming, Mgr.
Chicago, Ill. ..... W. D. Foreman, 22 E. 18th St.
Cincinnati, Ohio ..... Wirthlin-Mann Co., 318-320 West Third St.
Cleveland, Ohio ..... Chain & Sprocket Service Co., 1794 East 55th St.
Detroit, Mich. ..... Baldwin Service Co., 8641 Woodward Ave.
Kansas City, Mo. ..... Motor & Machinists Supply Co., 1617 Grand Ave.
Kansas City, Mo. ..... The Facth Company, 1117-1131 W. Eighth St.
Los Angeles, Calif. ..... Colyear Motor Sales Co., 1222-1228 South Hill St.
Minneapolis, Minn. ..... Baldwin Service Co., 39 South 11th Street
New Orleans, La. ..... M. H. Rykoski, 706-708 Julia St.
New York City ..... C. D. Schmidt Co., 276 Canal St.
Philadelphia, Pa. ..... N. A. Petry Co., Inc., 328-334 North Randolph St.
Portland, Oregon ..... H. W. Sharp Co., 68-70 First Street
Providence, R. I. ..... Lanphear Motor Car Co., 17 Snow St.
San Francisco, Calif. ..... The Adam-Hill Co., 96 Ninth St.
Seattle, Wash. ..... Wade & Co., 1423 Twelfth Ave.
St. Paul, Minn. ..... C. J. Smith Co., 155 W. Fifth St.
St. Louis, Mo. ..... American Automobile & Supply Co., 3200 Locust St.
Montreal, Toronto, Winnipeg, Can. ..... Lyman Tube & Supply Co., Limited

BALDWIN CHAIN & MFG. CO.
WORCESTER, MASS.

H. V. GREENWOOD, *Western Sales Representative*
PEOPLES GAS BUILDING, CHICAGO, ILLINOIS

GENUINE BALDWIN CHAINS

POSITIONS AVAILABLE
Concluded

135 RESEARCH ENGINEER to take charge of lubrication department of Government laboratory at Washington.

136 EXPERIMENTAL ENGINEER to take charge of exhaustive tests of tractors under state law and also conduct experimental and research work on farm machinery.

137 GENERAL MANAGER who is capable of reorganizing and operating an automobile plant producing a car of the high-grade medium price class. Must have wide experience and reputation with some good firm.

138 SHOP SUPERINTENDENT or production man for a high-grade brass plant employing at present 110 people. Must be familiar with modern shop practice and a real producer. Located in a Michigan town of about 5000 people, 100 miles from Detroit.

139 INSTRUCTOR to take charge of automotive school opening July 1. Technical training, executive and promoting ability, and some actual work as a mechanic desirable. Location, Toledo.

140 SALES ENGINEER Manufacturer of electrical equipment requires traveling sales engineer to sell product to manufacturers of high-grade automobiles and gasoline engines. Unusual opportunity for first-class man having broad selling experience.

141 FACTORY OR PRODUCTION MANAGER for automobile plant getting ready to produce 3000 cars per year. Location Pennsylvania.

142 SHOP SUPERINTENDENT to take active charge of a gear manufacturing shop. Sales experience essential. A man able to secure business, make quotations and direct the production is desired.

143 ENGINEER wanted to take charge of experimental department of a Middle West automobile, truck and tractor plant.

144 ENGINEER experienced in gear design, manufacture and research desired by a Detroit automobile builder.

145 TRANSPORTATION ENGINEER is desired by Middle West truck company. Duties will be the collection of data covering competitive trucks, accessories and equipment; and engineering questions. Will do some traveling making surveys of various territories from the vocational standpoint.

146 ENGINEER who is experienced in ignition work. Drafting experience essential. Good opportunity for advancement. Location Pennsylvania.

147 ENGINEER with unusual experience and knowledge of wheels to assist in the development, research work and testing of a new steel wheel.

GENERAL DROP FORGE CO.
SPECIAL DROP FORGINGS OF ALL KINDS TO ORDER
SEND US PRINTS OR MODELS FOR PRICES
BUFFALO, N. Y.

A Complete Line of Quality

LEATHER H L B

Fan Belts and Parts

"Weldrufe" Flat Fan Belting.
Vee Lug Fan Belting.
Vee Sol. "V" Fan Belting.
Vee Flex. "V" Fan Belting.
Fan Belts for all Motor Vehicles.

Leatheter Cone Clutch Facings.
Disc Clutch Facings.
Anti-Squeak Frame Padding.
Leather Tire Straps and Cut Lacings.
Discs, Boots, Gaskets, Washers, etc.

Write for Catalog and Prices.

Hide Leather & Belting Co. **Indianapolis**

COUNTER BALANCED CRANK SHAFTS

MADE BY

The PARK DROP FORGE CO.
CLEVELAND, OHIO

Quality Predominates

The big reason why so many Gilmer products are used by automotive manufacturers lies in the fact that every Gilmer product is *basically* constructed to overcome every obstacle to superior service. That is why over 80% of the cars made in America are factory equipped with Gilmer Woven Endless Fan Belts.

The following Gilmer Woven Products are widely used as regular equipment.

Woven Endless Fan Belts
Body, Spring and Radiator Shims
Radiator and Hood Lacing
Transmission Lining
Rebound Straps
Top, Tire and Door-check Straps
Strainer Web
Webbing for all purposes

TRADE MARK
Gilmer
WOVEN PRODUCTS

L. H. GILMER CO.
Philadelphia, Pa.

KELLOGG TIRE PUMPS
KELLOGG MANUFACTURING COMPANY, ROCHESTER, N.Y., U.S.A.

G & O Radiators

THE G & O MANUFACTURING CO.
NEW HAVEN CONN.

BENDIX
ECLIPSE
DRIVE
for ELECTRIC STARTERS

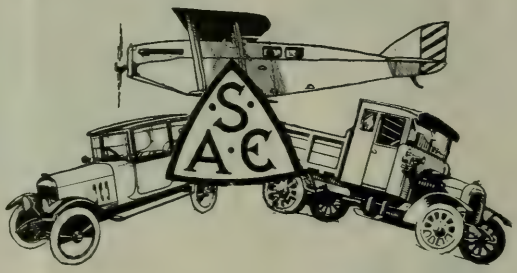
AUTOMATIC ENGAGING & DISENGAGING

194 Motor Car and Truck Builders Use It

ECLIPSE MACHINE CO.
ELMIRA - N.Y. -

ACME-DIE

· CASTINGS ·
ALUMINUM · ZINC · TIN & LEAD ALLOYS
Acme Die-Casting Corp.
Boston Rochester Brooklyn N.Y. Detroit Chicago



The Circulation of This Issue of the Journal Is 6500

Does your advertising manager appreciate that the men who read the JOURNAL hold responsible positions in the industry in the following classes:

Chief Engineers
Staff Engineers
Consulting Engineers
Production Engineers
Factory Managers
Tool Engineers
Executive Officers
Service Engineers
Designers
Draftsmen
Purchasing Agents

You know that you read the JOURNAL with unusual interest and depend upon its advertising section to keep you acquainted with the newest developments in the industrial field. If you are engaged in producing material that is sold to men in the automotive field, you must realize the effectiveness of advertising in the JOURNAL.

Maybe your company's advertising is not included in this month's advertising section, and we generally find that this is because your advertising manager may not only be unfamiliar with the existence of the JOURNAL, but he even may not know of the S. A. E. and the important position it has in the industry. Show him this number and suggest that he write to our advertising department for information as to rates, etc.

REDMANOL

Perfect Moulded Insulation

It excels in

Heat Resistance
Dielectric Strength
Mechanical Strength
Acid Resistance
Accuracy of Dimensions

Redmanol Chemical Products Co.
643 W. 22nd St., Chicago. Ill.

STEEL
TOOL
FRASSTEELS
ALLOY

For Immediate Delivery

S. A. E. STEELS

2320-2340-3120
3140-3440

LARGE STOCKS
Inquiries Solicited

Manufacturers
Frasse Steel Works
Incorporated
HARTFORD, CONN.

Distributors
Peter A. Frasse & Co., Inc.
417 Canal St., New York
Philadelphia Buffalo

American Hammered Piston Rings

American Hammered Piston Ring Co.
BALTIMORE, MD.
EXPORT DEPT., 461 EIGHTH AVE., NEW YORK, N. Y.

KARLOK

Mr. Producer and Designer

Besides the protection from theft, Karlok carries with it a 15% reduction on theft insurance premiums. This will prove an inducement to prospective buyers of your car.

Write for particulars.

Karlok Manufacturing Co.
Newark, N. J.

Raybestos MOLDED CLUTCH FACING

PATENTED – GUARANTEED

THE RAYBESTOS COMPANY

FACTORIES:
Bridgeport, Conn.; Peterborough, Ont., Can.

BRANCHES:

DETROIT .....4857 Woodward Ave.
CHICAGO .....332 South Michigan Ave.
SAN FRANCISCO .....1403 Chronicle Building
WASHINGTON, D. C. .....107 Columbian Building

CUT DOWN FRICTION

USE CROFOOT GEARS

Users of Crofoot Gears are getting the extra power that is usually wasted when ordinary gears are used.
Crofoot Gears are made with such microscopic accuracy that all avoidable friction is entirely eliminated.
Result: more power, less noise.

Made in all types and sizes and in any quantity.

Screw machine work up to 5" diameter. Precision grinding of every description up to 6" diameter for external work and up to 5" diameter for internal work.

Spurs
Bevels
Mitres
Spirals
Helicals
Worms
Worm Gears

Member American Gear Manufacturers' Association

Crofoot Gear Works, Inc.
Hyde Park Ave., at Readville
BOSTON, 37, MASS.

SHEET METAL STAMPING

We are building axle housings, brake drums, and other parts for the heaviest motor trucks ever built, and have ample capacity for still heavier.

With our complete equipment we cover the entire sheet metal stamping line.

We solicit your inquiries.

THE CROSBY COMPANY

DETROIT OFFICE: 914 Ford Bldg. BUFFALO, N. Y. CLEVELAND OFFICE: 415 Schofield Bldg.
New York Office: 30 Church Street

COMFORT

Houdaille Hydraulic
(*say Hoo-dye*)
Shock Absorbers

GIVE absolute comfort to every car. Prevent body sway, spring breakage; check rebound.

Houdailles are standard equipment on leading European cars, such as Delage, Minerva, Panhard, Pic-Pic, Peugot, Rochet-Schneider, etc., also American Cunningham and new Duesenberg Straight 8.

THE HOUDAILLE CO.

1435 Root Bldg. Buffalo, N. Y.

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Wyman-Gordon Co.

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Battery Parts
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Bearing Metal, Bronze
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Gurney Ball Bearing Co.
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Norma Co. of America.
S K F Industries, Inc.
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American Bronze Corporation

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Hyatt Roller Bearing Co.
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Hide Leather & Belting Co.

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Bumpers, Rubber
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Bound Brook Oil-less Bearing Co.

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QUALITY
SNAP RINGS
More Than
a Million a Month
Another
FEDERAL
THE Federal
Motor Truck
is *also* equipped
with Quality Snap
Rings. . . . . .
THE Piston RING COMPANY
MUSKEGON, MICH.

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Link-Belt Co.

Chains, Automobile Engine
Link-Belt Co.
Morse Chain Co.
Whitney Mfg. Co.

Chains, Block
Morse Chain Co.
Whitney Mfg. Co.

Chains, Silent
Link-Belt Co.
Morse Chain Co.
Whitney Mfg. Co.

Chains, Sprocket Wheel
Link-Belt Co.
Morse Chain Co.
Whitney Mfg. Co.

Chains, Transmission or Driving
Baldwin Chain & Mfg. Co.
Link-Belt Co.
Morse Chain Co.

Channels, Pressed Steel
Parish Mfg. Corporation

Chucks, Quick Change
Whitney Mfg. Co.

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Schrader's Son, Inc., A

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Williams, J. H., & Co.

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American Vulcanized Fibre Co.

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Covert Gear Co.
Fuller & Sons Mfg. Co.
Hartford Automotive Parts Co.
Link-Belt Co.

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Acme Wire Co.

Collars, Ball Bearing
Bantam Ball Bearing Co.

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Williams, J. H., & Co.

Connections, Tire Pump
Schrader's Son, Inc., A.

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Long Mfg. Co.
United States Cartridge Co.

Couplings, Flexible
Thermoid Rubber Co.

Cranes, Portable Electric
Baker R & L Co.

Cranks, Starting
Steel Products Co.

Crankshafts
Jefferson Forge Products Co.
Park Drop Forge Co.
Williams, J. H., & Co.
Wyman-Gordon Co.

Cutters, End Mill
Haynes Stellite Co.

Cutters, Keyway
Whitney Mfg. Co.

Cutters, Milling
Haynes Stellite Co.

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Parish Mfg. Corporation

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New Process Gear Corporation
Ross Gear & Tool Co.

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Hide Leather & Belting Co.
Thermoid Rubber Co.

Discs, Steel Clutch
Motor Wheel Corporation

Drive, Electric Motor
Eclipse Machine Co.

Drives, Silent Chain
Link-Belt Co.
Morse Chain Co.
Whitney Mfg. Co.

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Parish Mfg. Corporation

Drums, Pressed Steel Brake
Crosby Co.
Hydraulic Pressed Steel Co.
Ireland & Matthews Mfg. Co.
Motor Wheel Corporation
Parish & Bingham Corporation

Dynamic and Static Balancing
Vibration Specialty Co.

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Wisconsin Motor Mfg. Co.

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Wisconsin Motor Mfg. Co.

Engines, Tractor
Light Mfg. & Foundry Co.
Weidely Motors Co.
Wisconsin Motor Mfg. Co.

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Wisconsin Motor Mfg. Co.

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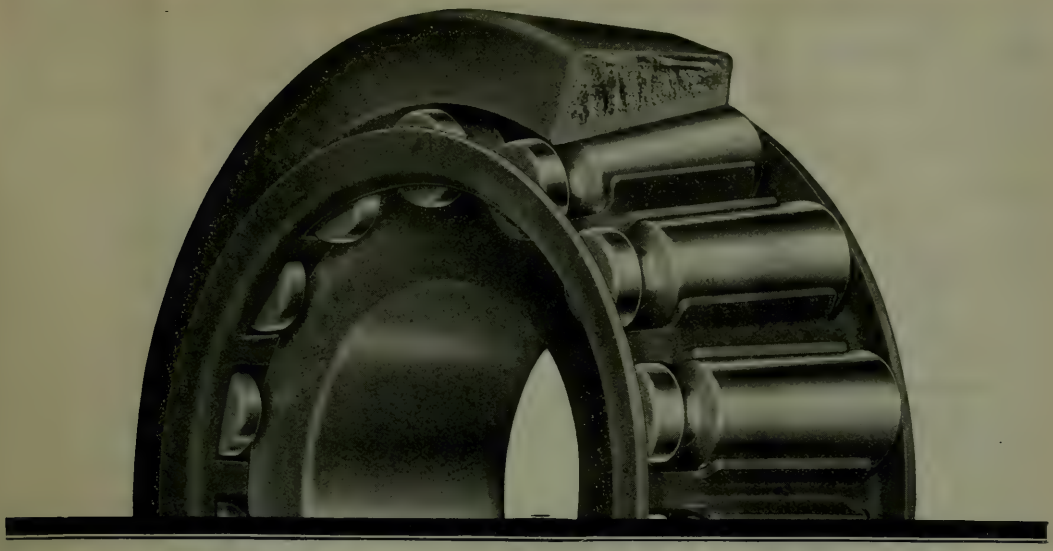

Sound Engineering

That the Timken principle of adjustability is sound engineering is attested to by general engineering practice throughout every motor driven vehicle.

In all the important working parts about a motor vehicle that are subject to wear from motion, adjustment is uniformly provided.

Bronze bushings are placed in the spring eyes; shims are used in the main bearings of the motor; tapered adjustment is provided in the steering gear; take-up for wear resulting from motion is engineered into the clutch, into the brakes, in the cam shaft mounting; and even such parts as carburetor, valves, carburetor springs, ignition devices, etc, are all provided for adjustment or take-up for that wear which *must* follow motion.

It is not surprising that designing engineers should be responsible for the use of more than fifty-seven million Timken Tapered Roller Bearings in 422 American and European passenger cars, trucks, tractors, and trailers.

The Timken Roller Bearing Co, Canton, O

Timken Tapered Roller Bearings for Passenger Cars, Trucks, Tractors, Trailers, Farm Implements, Machinery, and Industrial Appliances

TIMKEN
Tapered
ROLLER BEARINGS

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Hydraulic Pressed Steel Co.
Motor Wheel Corporation
Parish & Bingham Corporation

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Perfection Heater & Mfg. Co.

Heaters, Mixture
Master Primer Co.

Horns, Automobile
E. A. Laboratories, Inc.
North East Electric Co.
Sparks-Withington Co.

Hose, Gasoline
Thermoid Rubber Co.

Hose, Radiator
Thermoid Rubber Co.

Hubs, Motor Vehicle
Motor Wheel Corporation

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Houdaille Co.

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Norma Co. of America

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Goodrich Rubber Co., B. F.

Joints, Universal
Hartford Automotive Parts Co.
Spicer Mfg. Corporation
Thermoid Rubber Co.

Keys, Woodruff
Whitney Mfg. Co.

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Olsen Testing Machine Co., Tinius

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Linings, Brake
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Raybestos Co.
Thermoid Rubber Co.

Linings, Frame
Gilmer Co., L. H.

Links, Drag
Steel Products Co.

Locks, Automobile
Karlok Mfg. Co.

Locomotives, Industrial, Electric
Baker R & L Co.

Lubricants
Dixon Crucible Co., Jos.
Texas Co.

Lubricating Systems
Ireland & Matthews Mfg. Co.

Lubricators
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Magnetos
Teagle Co.

Molded Machine Equipment
Standard Pattern Works of Detroit, Inc.

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Pumps, Oil
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One of our friends has described Disteel Wheels as spokeless and speechless. He is right. They are wheels that never "talk back."

If you have experienced the annoyance of squeaking, rattling motor car wheels you will appreciate this Disteel advantage immediately. Like soup and children wheels should be seen but not heard.

Exclusive Manufacturers: **Detroit Pressed Steel Company**

New York Boston **DISTEEL WHEEL CORPORATION** Chicago San Francisco

DETROIT, U. S. A.

DISTEEL WHEELS

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Steel, Bessemer and Open-Hearth
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Union Drawn Steel Co.

Steel, Chrome
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Steel, Chrome Nickel
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Union Drawn Steel Co.

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Interstate Iron & Steel Co.

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Bound Brook Oil-less Bearing Co.

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Acme Wire Co.

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What Counts in Producing Frames

Equipped with Hydraulic Frame

The quality of steel and the character of workmanship are of fundamental importance in producing *good* frames.

Hydraulic rolls its own steel and builds frames in its own plant. From furnace to finished product all operations are under Hydraulic control. Hydraulic *knows* that the high standard of quality for steel *is* maintained.

The men look upon their work as not merely a task to be completed, but a service to be performed. They take pride in accomplishment. They have an interest in their work. Care, thought and skill are combined into a high order of workmanship, which is reflected in the splendid service which *every* Hydraulic Frame renders.

THE HYDRAULIC PRESSED STEEL COMPANY
of THE HYDRAULIC STEEL COMPANY
CLEVELAND, OHIO

Manufacturers of

Pressed Steel Frames for Passenger Cars, Trucks and Tractors; Axle Housings; Brake Drums; Torque Arms; Running Boards; Step Hangers; Hub Flanges; Discs; Dust Shields; Steel Barrels; Aeroplane and Miscellaneous Stampings.

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Chicago
Fisher Building

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HYDRAULIC
FRAMES

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Whether used on motor cars, trucks or tractors, Long Cooling Systems assure continuous service, uninterrupted by any radiation trouble.

Our Engineering Department Can Assist You

Each Long Cooling System is designed to order for each type of motor with which it is to be used. Each step in creating the design is taken in co-operation between the Engineering Departments of our factory and those of the manufacturer. Proper design insures proper construction. By reason of this co-operation, Long Cooling Systems represent minimum cost and maximum efficiency.

Let us confer with you regarding your radiation problems.

LONG MANUFACTURING CO., DETROIT, MICHIGAN

Pioneer Makers of Cooling Systems for Gasoline Engines

LONG
COOLING SYSTEMS

The Recognized Standard for Tractors, Trucks and Motor Cars

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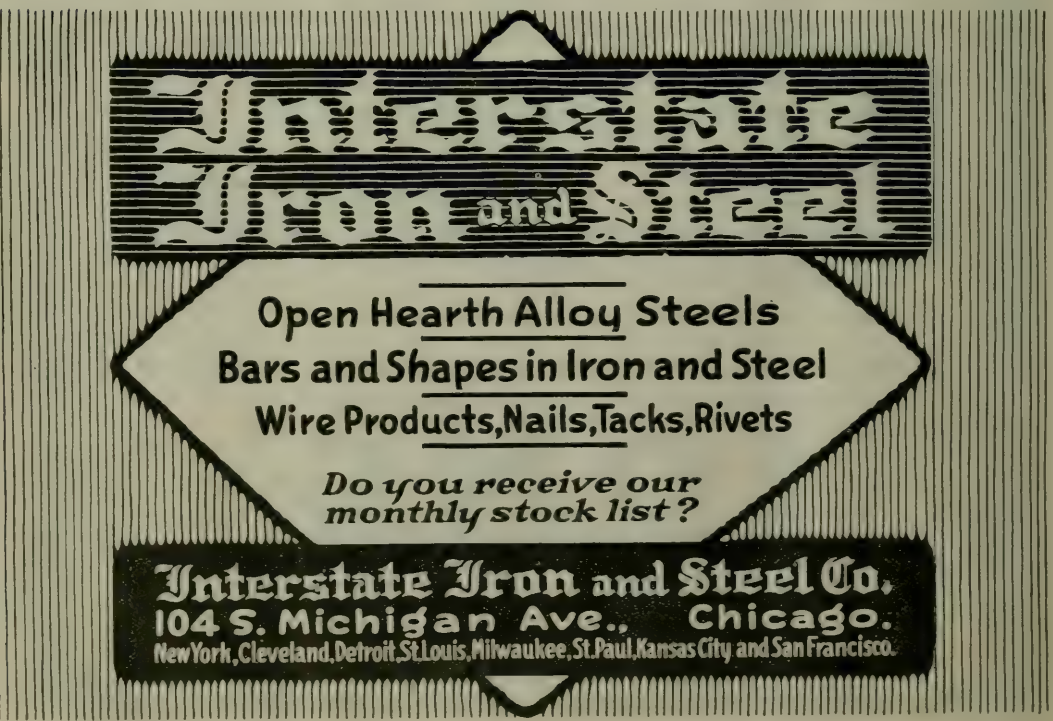
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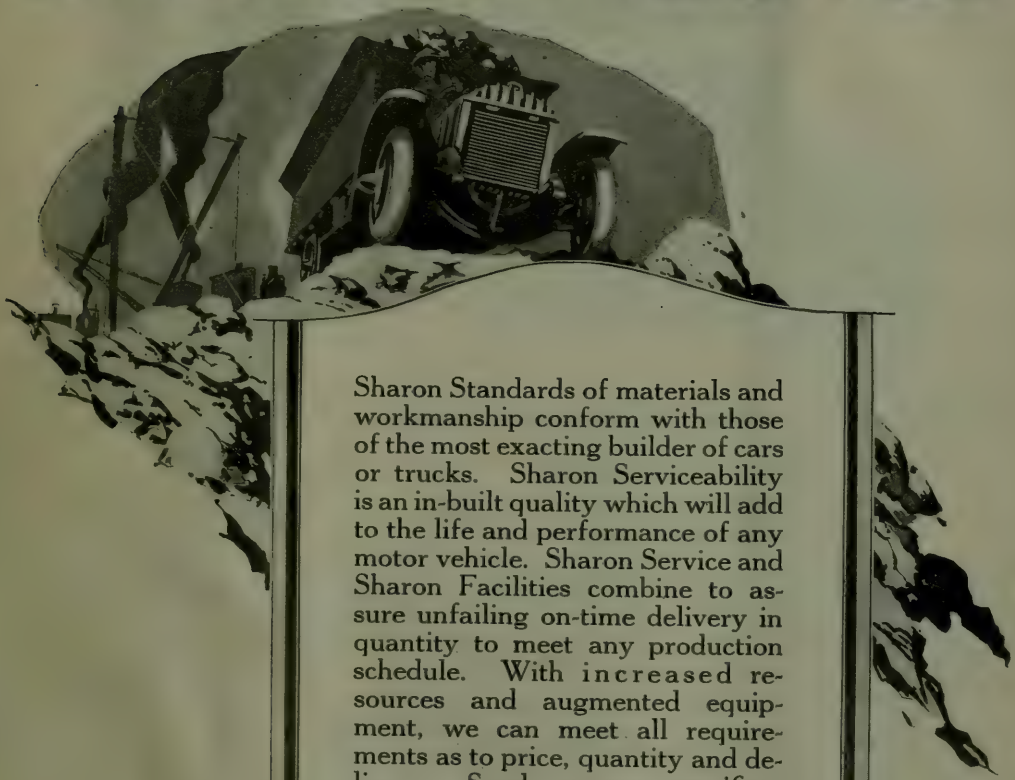
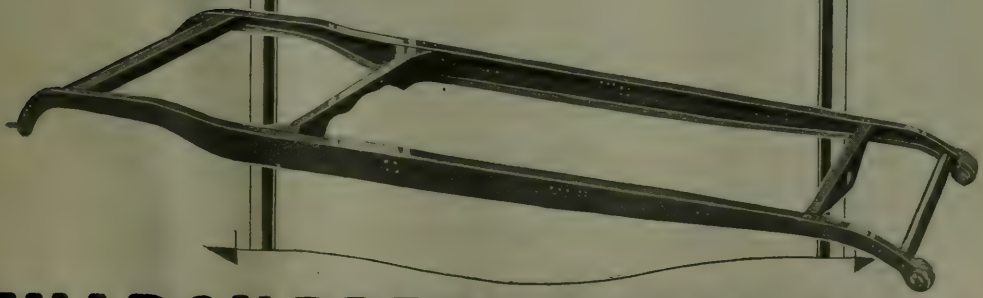
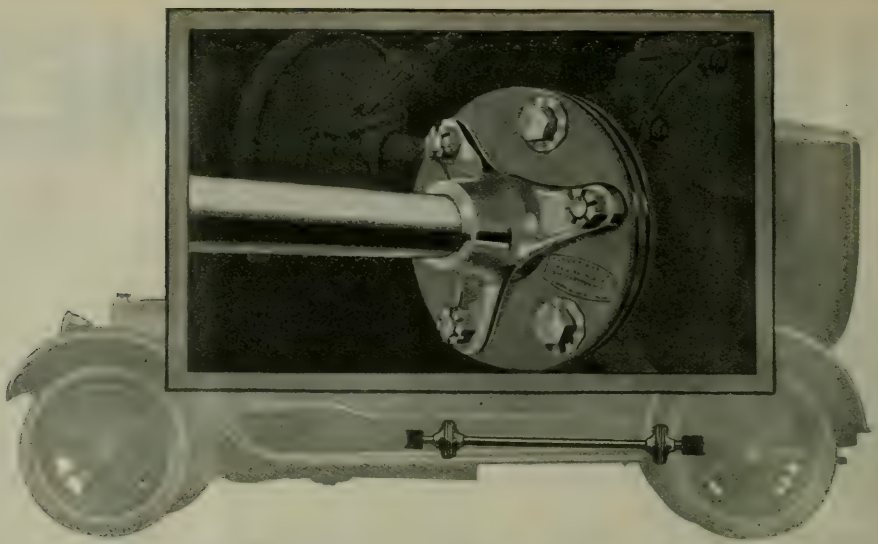


Sharon Standards of materials and workmanship conform with those of the most exacting builder of cars or trucks. Sharon Serviceability is an in-built quality which will add to the life and performance of any motor vehicle. Sharon Service and Sharon Facilities combine to assure unfailing on-time delivery in quantity to meet any production schedule. With increased resources and augmented equipment, we can meet all requirements as to price, quantity and delivery. Send us your specifications. Let our engineers work with yours.



SHARON PRESSED STEEL CO.

MAIN OFFICE AND WORKS, SHARON, PENNA.



Cushioning the twisting blows in the drive shaft

How the flexible Thermoid-Hardy Universal eliminates jolts and jars

YOU throw in the clutch and the whole power of the engine hits the car a sudden blow. This is what happens with metal universal joints. Drive shaft, transmission, rear axle assembly—in all, 15 gears and 12 bearings feel the strain.

Metal joints fail to cushion the blows of starting, of rapidly shifting gears, of going over rough roads. Metal joints soon wear loose, causing rattle and backlash—the danger signal for trouble to follow.

The Thermoid-Hardy Universal Joint embodies a new principle in construction. There are no metal parts to grind together or wear loose. Instead, the joint is made up of fabric discs—so flexible that every jolt and jar of the road is absorbed—so tough and durable that they can be used to twist a steel propeller shaft at a stress of more than 21,000 pounds. Noise, vibration, backlash, and power loss, so common with metal universals, are eliminated. There is a smooth, even flow of power from engine to rear axle.

Fanwise construction for strength

The patented scientific process by which Thermoid-Hardy Universal Joints are constructed is the reason for their great strength and durability. The flexible discs are built up from layers of long strand Sea Island cotton duck and a special friction rubber compound. The layers are arranged fanwise in the well-known Thermoid-Hardy formation, so that the strands of cotton in the various plies run in different directions. The layers are finally welded together under hydraulic pressure until the disc becomes one compact, inseparable mass with a tensile strength of 3,400 pounds per square inch.

No attention required

Thermoid-Hardy Universal Joints need no lubrication or adjustment. They are absolutely silent in operation and impervious to mud, sand, oil or water.

Fifty leading manufacturers of passenger cars and trucks have adopted Thermoid-Hardy Universal Joints as standard equipment.

You should have this book—sent free to any dealer or engineer

We have prepared a book, "Universal Joints—Their Use and Misuse," that treats the whole subject from all its angles—the mechanical principles involved, construction, lubrication, processes of manufacture, tests for strength, and records of performance. It explains why so many leading engineers have adopted the Thermoid-Hardy Universal Joint. Send for a copy to-day.

THERMOID RUBBER COMPANY

Sole American Manufacturers

Factory and Main Offices: Trenton, N. J.

New York, Chicago, San Francisco, Detroit, Cleveland, Atlanta, Pittsburgh, Boston, London, Paris, Turin

THERMOID-HARDY
UNIVERSAL JOINT

Fanwise construction for strength

Makers of "Thermoid Hydraulic Compressed Brake Lining" and "Thermoid Crolide Compound Tires"

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Hawkeye Truck Co.
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Sprague Electric Co.
Stoughton Wagon Co.
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Stutes Mar Tractor Co.
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Tioga Steel & Iron Co.
Tow Motor Co.
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Transport Truck Co.
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United Motors Co.
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